HOUSE OF COMMONS SESSION 1995–96

SCIENCE AND TECHNOLOGY COMMITTEE

Fourth Report

THE PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL

Volume II

Minutes of Evidence and Appendices

Ordered by The House of Commons *to be printed*
11th July 1996

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The Science and Technology Committee is appointed under SO No 130 to examine the expenditure, administration and policy of the Office of Science and Technology and associated public bodies.

The Committee consists of 11 Members. It has a quorum of three.

The Committee has power:

(a) to send for persons, papers and records, to sit notwithstanding any adjournment of the House, to adjourn from place to place, and to report from time to time;

(b) to appoint specialist advisers either to supply information which is not readily available or to elucidate matters of complexity within the Committee's order of reference;

(c) to communicate to any other such committee and to the Committee of Public Accounts and to the Deregulation Committee its evidence and any other documents relating to matters of common interest; and

(d) to meet concurrently with any other such committee for the purposes of deliberating, taking evidence, or considering draft reports.

Unless the House otherwise orders, all Members nominated to the Committee continue to be members of it for the remainder of the Parliament.

The following were nominated Members of the Committee on 13 July 1992:

Mr Spencer Batiste
Dr Jeremy Bray
Mr Malcolm Bruce
Mrs Anne Campbell
Cheryl Gillan
Mr William Powell
Sir Giles Shaw
Sir Trevor Skeet
Dr Gavin Strang
Sir Gerard Vaughan
Dr Alan W Williams

Sir Giles Shaw was elected Chairman on 15 July 1992.

On 9 November 1992 Mr Malcolm Bruce was discharged and Mr Andrew Miller added to the Committee.

On 16 November 1992 Dr Gavin Strang was discharged and Dr Lynne Jones added to the Committee.

On 7 November 1995 Cheryl Gillan and Mr William Powell were discharged and Mr Ian Bruce and Mr Patrick Thompson were added to the Committee.

The cost of preparing for publication the shorthand minutes published with this Report was £2,226.99
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MINUTES OF EVIDENCE

TAKEN BEFORE THE SCIENCE AND TECHNOLOGY COMMITTEE

WEDNESDAY 21 FEBRUARY 1996

Members present:

Sir Giles Shaw, in the Chair

Mr Spencer Batiste	Sir Trevor Skeet
Dr Jeremy Bray	Mr Patrick Thompson
Mrs Anne Campbell	Sir Gerard Vaughan
Dr Lynne Jones	Dr Alan Williams
Mr Andrew Miller	

Letter to the Clerk of the Committee from Professor J L Culhane (16.12.95)

I write on the above as a Space Scientist and Director of the UK's largest University-based institute which pursues a broad programme in Climate Physics, High Energy Astrophysics, Solar Physics and Space Plasma Physics. I am also a non-executive director and currently Board Chairman of a small space hardware and software company—Satellites International, with an annual turnover of £1.5 million. I will comment in the areas mentioned in your Press Notice on 19 October with particular emphasis on the space-related disciplines.

(i) Importance of continued UK participation in "Big Science" projects

It is important for the UK as a civilized and developed nation to continue participation in the fundamental "big science" fields—Astronomy, Space and High Energy Physics, for both cultural and economic reasons. Continued leadership in fundamental science is important for national self esteem. However, albeit indirectly and on a timescale of decades, fundamental science does create wealth and improve the quality of life. The link from Quantum Physics to semiconductor devices and the resulting explosive growth of electronic and information technologies provides an obvious example. In the shorter term there are also examples of closer coupling—use of SERC/PPARC funded X-ray Astronomy Charge Coupled Devices (CCDs) for dental X-ray imaging. PPARC since its inception has sought such opportunities and with the PPARC Industrial Programme Support Scheme and the operation of its Industrial Programme Advisory Committee of which I am a member, has put in place mechanisms to enhance the already close relationships with UK industry.

UK Participation in the "big sciences" does require involvement in large scale international collaborations. This is true of the Astronomy, Space and High Energy Physics fields given the large-scale nature of the required facilities. For Space in particular, membership of the European Space Agency (ESA) represents the only realistic route for UK scientists to maintain their world front rank positions in Astronomy and Space Physics. While modest bilateral involvements in the programmes of other nations are important (see below), they provide no long term rights for participation and no ability to tailor the programmes to UK needs. Membership of ESA however requires skillful negotiation by UK representatives to secure our aims and interests. Since the activities of the Agency embrace a broad range of space-related topics with Science representing only 12 per cent of the overall programme volume—unlike CERN which is wholly devoted to a basic science programme—it is vital for UK representatives to be effective networkers within Europe and to be aware of the broad range of UK Space interests involved in ESA.

Growth of the national subscription for membership of the ESA mandatory programme which includes Space Science has had a disastrous impact on our ability to participate in the Agency's scientific programme (see below). While pressing energetically for necessary reforms within ESA, it is important to recognize that it is the entire Agency that requires reform—the science programme represents in fact the most successful part of the activity. Thus the subscription payments should be protected in the short term to avoid repeating the damage to UK involvement in individual science missions as has happened recently in the case of INTEGRAL. However medium and long term reform of the Agency at large is essential and the recent ministerial meeting in Toulouse has made an excellent beginning in this area.

(ii) UK Scientific Exploitation of International Collaborative Facilities

In Space the scale of programmes and current high cost of launching payloads into orbit have made a collaborative approach essential. Thus the UK activity continues to include membership of ESA and modest bilateral involvements in the space programmes of other nations. In the latter area work with the USA and more recently Japan has been particularly cost-effective. Exploitation of ESA membership has been increasingly difficult in the past few years because of the growing fraction of the PPARC budget that is taken up by the subscription. Following the successful outcome of the recent meeting of European space ministers in Toulouse, the UK has secured the capping of its subscription with a resulting saving of ~£15 million over the next five years. It is therefore of the utmost importance that PPARC be enabled to restore its "domestic" support of the ESA programme to 25 per cent to 30 per cent of the subscription or ~£10 million/annum[1].

Running at this level over the past decade has enabled the UK to win a more than pro rata share of Principal Investigator (PI) roles in the ESA space missions. This in turn has allowed scientific return to UK groups that is much enhanced in relation to the 14 per cent share of the ESA programme which the UK subscription represents. In addition the UK remains the largest supplier of new mission ideas among the member states. Continued reduced domestic support in the UK will make it impossible for UK scientists to take up opportunities within ESA. Initially this will have the effect of subsidising the researchers in other member states. In the longer term it will destroy the current UK world position in fields like Space Astronomy and Space Physics and because of our current pre-eminence, significantly weaken these disciplines in Europe.

In order to maintain the strength of the UK programme, it is important to provide more modest resource for bilateral programmes with nations such as USA and Japan. Such involvements arise on an opportunistic basis. Thus we are unable in a formal sense to influence the choice of missions as we do in ESA but in appropriate cases can obtain substantial scientific benefit without contributing to the cost of the spacecraft or the launcher. Our involvement in the Japanese Yohkoh mission (launched in August 1991) in Solar Physics gives an excellent example. Here we provided an instrument at a cost to the UK of ~£1.5 million but, as a PI group, gained access to all of the mission data and related software for the entire UK community. While our main involvement in the field must be through ESA as described above, support of bilateral programmes at an average level of ~£2 million/annum is essential for the overall health of the programme and gives excellent value for money.

(iii) MANAGEMENT AND FUNDING OF MAJOR INTERNATIONAL PROJECTS

In the Space field, although many of the spacecraft, their launches and operation in space require substantial resource—£350 million would be a typical current figure for an ESA mission, a significant or PI UK national involvement in an individual instrument requires a small fraction of this ie, ~£10 million or less. Following the move by NASA towards smaller missions and shorter timescales, pressure is mounting on ESA to follow in the same direction. Thus individual UK involvements are not likely to grow in scale. There are several large UK University groups with established track records in the development, construction, management and flight of space instruments. These groups have tended to establish collaborative links with smaller groups and with scientists at DRAL to form winning consortia by making use of the best available techniques and skills. Thus the kind of central management provided by DRAL for the High Energy Physics community to participate in the very large instrument programmes required at CERN is not required in the Space field. The trend to small missions will encourage this mode of operation which requires fast response, innovation and low costs. Where there are appropriate technologies and, more importantly, relevant large-scale test facilities at DRAL, they can be incorporated competitively into teams developing and providing instrumentation for space missions.

Funding of Space Science is at present by PPARC—partly through the grants line and partly through special provision for individual projects. Both of these sources are under considerable pressure because of the recent catastrophic reduction in the level of domestic resource available for support of the ESA programme. If the overall levels of domestic programme provision and resource for modest bilateral involvements can be restored to the figure of ~£12 million/annum mentioned in (ii) above, the present system of competitive peer review which awards these resources through standing committees and special review panels could be again effective. Because of the exceptional long-term importance of advanced instrumentation development for our future in the subject, for student training and for the transfer of novel technologies to UK industry, it may be necessary to provide special measures and incentives in this area within the £12 million overall figure.

(iv) HOW APPROPRIATE IS THE STRUCTURE OF PPARC FOR ITS RESEARCH PORTFOLIO?

Although access to Space may at one level be regarded simply as a means of enabling a range of basic sciences to be undertaken, the high costs, specialist technologies, harsh environment and wide range of important national interests involved all require that we take a broad view of the subject. Following its formation, some of the structures put in place by PPARC for dealing with the Space portfolio could undoubtedly be improved. In order to ensure that appropriate value is obtained from the ESA subscription, the provision of resource for the domestic space programme should be made more explicit and the PPARC committee structure should be modified to reflect this. Thus Council would become better informed on the nature and conduct of an important component—about 25 per cent of its overall programme and be in a position to provide advice in the context of the broader UK space and industrial interests. The annual UK science subscription to ESA of almost £40 million requires the careful and consistent attention of appropriately knowledgeable staff who can network successfully within the BNSC, UK Space Industry, ESA and in the wider European context. This is necessary to ensure that UK scientists can compete with maximum effectiveness for involvement in the available mission opportunities and to maintain pressure on ESA to institute necessary reforms.

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[1] While the mandatory ESA subscription paid by each member state enables the production, launching and operation in orbit of spacecraft, each nation must bid competitively for scientific involvement in the Agency's missions and fund the production of scientific instruments and the exploitation of the resulting data by its own community.

Letter to the Clerk of the Committee from Professor George Kalmus (27.11.95)

I am responding to your request for written evidence in your inquiry into PPARC.

I am particularly concerned with the UK experimental particle physics programme for which I have some responsibility. In your press release of 19 October 1995 you list four areas of particular interest to your Committee, I would like to address all of these:

1. Importance of "big-science projects such as the Large Hadron Collider".

   The way to a better understanding of the ultimate constituents of our Universe lies in resolving finer and finer structures and the ability to create more massive "fundamental" objects. In order to achieve this, high energy accelerators are needed equipped with detectors having great resolving powers. The latest manifestation of this need is the LHC with its suite of detectors.

   There is, I believe, no significant dissent in the world wide particle physics community that by far and away the most likely route to making new discoveries which will further illuminate our understanding is by going to the highest possible energies with the finest possible detectors.

   The LHC and its proposed suite of detectors is, for the present, the only facility and the world community is flocking to it. It is probably worth mentioning briefly some features of it and its experimental programme.

   Both the machine and the detectors are technically immensely challenging and require an enormous R&D effort to implement fully. Each experiment must be considered as a whole programme of research producing billions of individual pieces of data (events) per year. These then need to be analysed in a whole variety of different ways in order to address a whole spectrum of problems covering many (but not all) aspects of particle physics. It can in some ways be compared with a large telescope which works at different wave lengths and covers the whole sky simultaneously.

   Thus "big science projects like the LHC" are central to particle physics and as long as the UK wishes to remain a considerable force and influence in the international community it is mandatory to participate in this area of maximum excitement. We are very good at this type of work and are still highly regarded.

2. Are UK scientists able fully to exploit this type of collaborative facility?

   The short answer to this is yes in the past, just about in the present, but no in the future ie, for LHC, *unless* extra funding for the UK domestic programme is found. The UK experimental particle physics community is smaller than those of Germany, France and Italy and is funded at a lower level pro rata than any of these. Yet we are higly rated and still in great demand as collaborators. This is both because of the high quality of our physicists and engineers, but also crucially because the UK community is well organised and perceived to be highly efficient and trustworthy.

3. How should major international projects be managed and funded?

   I believe that the role of *managing* large international projects such as LHC should be left to the CERN management under its Director General. I have observed the way this works from close quarters as a member of the CERN Scientific Policy Committee (SPC) and believe that the checks and balances provided by the SPC, the CERN finance committee and the CERN Council are sufficient to ensure that the programme is well scrutinised and managed. The problems lie in other directions. They have to do with funding. The fact that CERN is entirely funded in swiss francs is and has always been a great problem. The swiss franc/pound exchange rate has continuously decreased over the last three decades and on occasions, as in the past three years, decreased by large percentages. This has put an incredible strain on the system not only because of the CERN subscription, but because CERN is *our* laboratory and we also spend a large fraction of our domestic budget on experiments at CERN. This extra money each year at present comes from the Science Vote. We are told that the extra for the CERN subscription does not come solely from the PPARC allocation but some inevitably must. It therefore has in effect to come from other Research Council's budgets and thus is a decrease in the funding of science in the UK. No volume increase in science is involved—it is purely the effect of a weak pound—presumably British industry and commerce benefit from this.

CERN is absolutely crucial for particle physics in the UK. It should be run as efficiently and as responsively as possible and mechanisms exist through the Finance Committee and the Council for the UK to bring pressure to bear to achieve this. Great strides have already been made.

However, the central problem of the ever decreasing domestic funding (in real terms) caused I believe in large part by the rise in value of the Swiss Franc, is that it threatens to undermine our future. There needs to be an increase of ~25 per cent (or ~£6.5M pa) in the domestic budget for the next 8–10 years for us to be able to participate in LHC experiments in a manner that is in any way commensurate with our ~£70M pa CERN subscription. It should be noted that PPARC Council does not have control of more than half of its total budget which goes on commitments defined by international treaties (CERN, ESA).

4. How appropriate is PPARC's structure for its research portfolio?

At first sight particle physics and astronomy have many common features not least of which is the fact that in the study of the origins of the universe (cosmology) and in aspects of astrophysics, measurements made in the laboratory by particle physicists and observations by astronomers are intimately linked. Another common thread is that both rely to a large extent on costly (and often large) equipment funded, in general, internationally. This is just as true for space missions, large ground based telescopes as for accelerators and detectors. However, there are important differences: astronomy is an observational science and particle physics is an experimental science. Also in most particle physics experiments data on all areas of interest are collected in parallel ie simultaneously, whereas in most astronomical observations data is collected in series eg looking at a particular part of the sky at a particular wavelength.

These differences mean that it is not easy to compare like with like and it is not at all clear that the most efficient way to organise the particle physics programme is also the best way to organise the astronomy programme. Indeed, they are very differently organised at present—the UK experimental particle physics programme being funded and managed largely through CCLRC with a very small number of rolling University grants (one per University) while the astronomy programme is, I believe managed directly by PPARC at Swindon with a large number of individual University grants. This results in a considerably larger central staff at Swindon in this latter area.

Perhaps, however, the real question is whether the Council of PPARC is constituted in a way which allows it to function properly and effectively?

Here I find myself in considerable difficulty since I approach the question inevitably from the view point of a particle physicist. It was I believe unfortunate to populate the Council initially with two particle physicists and four members from the astronomy community, including the CEO (the two areas are roughly equally funded). Although all members are appointed *ad hominem,* nevertheless it lacks balance. What I believe to be another important shortcoming of this body is the lack of any members who can put forward the scientific programme priorities and the views of the particle physics and astronomy communities to the Council. It is imperative that the Council has the chairpersons of the Particle Physics and Astronomy Committees as full members. This will ensure that the *ad hominem* members can act as such, rather than be proponents of their own areas of research, which as the only "experts" at Council meetings they inevitably become.

Finally, there is the question of the balance between the funding of the particle physics and astronomy programmes.

Here I find myself again in a quandary. I know intimately the problems of the particle physics programme but am much less familiar with the astronomy programme. I know that the particle physics programme is stressed to the point of breaking—we already have a relatively small community, sited at a small number of highly "research rated" universities and the Rutherford Appleton Laboratory (RAL). The gearing between the international subscription to the domestic programme is very high, about three to one. We are embarking on a new and exciting endeavour requiring the design and construction of the most advanced and challenging detectors ever contemplated. We are clearly on a very steep slope, an increase in funding is desperately needed to make our community effective and competitive in the future and justify the CERN subscription. A decrease would wreak quite disproportionate damage to our legitimate aspirations and cause a huge loss in our investment in the LHC.

I believe that rational decisions by the PPARC Council cannot be made while there is this enormous stress on the Councils' domestic funding. Any decision is certain to harm British science and our international standing. A relatively small increase in the UK domestic line would alleviate this problem and allow the PPARC Council to make rational decisions.

IN SUMMARY

(1) It is essential for the UK to participate in "big science" projects like the LHC and selected space missions—these are the main vehicles for progress in our subjects.

(2) UK particle physicists are exceptionally well organised to exploit such collaborative facilities, we have positions of considerable influence in their definition and operation. In the end we must, however, be adequately supported financially or we will lose it all.

(3) There has been a marked improvement in the management of CERN since the recommendation of the Abragam Committee. The CERN Council and its advisory bodies (Finance Committee and Scientific Policy Committee) should be able, if national representatives play a full part, to guide the direction of CERN. The detailed management must be left to the Director General.

(4) Some aspects of PPARC structure could be improved. The main problem however is the fact that there are inadequate resources for any future, cost effective domestic programme. Decision making between different parts of the programme is like making a choice as to whether to cut off a leg or an arm. It is irrational to expect a Council dedicated to promoting a healthy programme of high excellence to do this. If slightly more resources were available, then with the modifications I have indicated in the body of my letter, the Council is reasonably constituted.

I hope that these remarks will be of help to the deliberations of the Committee.

I would be quite prepared to give oral evidence to expand on any of the above points or any other areas should the Committee wish.

Memorandum from Professor Sir Martin Rees (29.12.95)

INTRODUCTION

This paper offers an individual perspective on some of the issues the Select Committee will be addressing. I write as a member of the PPARC council and a researcher in the sciences it covers.

The formal memorandum already submitted by PPARC highlights—I think quite fairly and cogently—the opportunities and problems facing this new Research Council. Sections 7 and 8 of that memorandum highlight some general concerns which I would strongly endorse. The Council has been fortunate in its Chief Executive, its Chairman, and its key staff, whose shared goals are to foster excellence and originality, and to optimise PPARC's distinctive contribution to UK science, technology and education.

If we could plan autonomously and from scratch, we would probably apportion our resources differently among the research areas PPARC covers. We would certainly not choose to tie up more than half our total budget (as it now is) in two international subscriptions over which we have limited leverage, leaving too little "free money" to properly benefit from them, and even less for supporting, even on a modest scale, outstanding UK initiatives within our remit.

Even if PPARC's scientific fields (the so-called "big sciences") were attracting the same fraction of the Science Vote as in the 1980's, readjustments would be severely constrained by several decades of history, by our membership of international partnerships, and by the inherently long-term nature of some scientific projects. Because the fraction of the budget allocated to the "big sciences" has fallen, PPARC has even less freedom of manouvre.

Despite PPARC's best efforts, its programme risks "seizing up" in a suboptimal state, where we live off the investment of the 1980's rather than being able to exploit the amazing new opportunities that advanced instrumentation and computers are opening up. "Cosmic" discoveries are now an undoubted highlight of the physical sciences—and the UK has recently been second only to the US in the standing of its scientists in this field.

THE INFRASTRUCTURE

The science covered by PPARC divides into three broad areas; associated with each is an infrastructure of shared facilities which constitute the first charge on our budget:

Particle physics—the CERN subscription may exceed £70 million next year because of the rise of the Swiss Franc.

Space science—the part of the ESA subscription falling on PPARC amounts to about £40 million.

Ground based telescopes—These are shared with international partners, but via ad hoc arrangements more under PPARC control; annual cost of operating our national observatories (including the two overseas sites in Hawaii and La Palma) is about £15 million.

In the overall financial perspective of science funding, this doesn't loom excessively large. As a fraction of the Science Vote, the infrastructure for ground based astronomy is 1.3 per cent, the ESA subscription about 3 per cent and the CERN subscription slightly over 5 per cent.

These three items (and the support of related research projects in universities) dominate PPARC's budget. If PPARC were freely establishing its priorities, it would almost certainly not have chosen this "mix". But the present situation is the outcome of history, and also of the difficulty of keeping in step with other countries whose funding systems for international "big science" are different from ours.

In the USA, particle physics and space science are funded by DOE and NASA respectively, not by NSF—if these fields of science competed with others for a share of a single budget, they would fare much less well. In most European countries, space science and international facilities are funded separately. Our system is more rational, but there are problems being the only one in step!

A Perspective on CERN

Our participation in CERN dates back to the 1950s. The scale of support for particle physics is a legacy of the prestige and clout of "nuclear" physicists in the post-WWII era. This led, world wide, to generous funding of particle physics. CERN is a legacy of this; CERN has also received repeated endorsements because of its success relative to the US, and because it has manifestly been a "flagship" of scientific excellence in a challenging field.

During PPARC's first year of operation (1994) the most important single issue within its remit was whether the UK should approve participation in the LHC, CERN's new accelerator. If we did, this would plainly preempt a large chunk of PPARC's funding throughout the next decade. Our Council unaminously favoured participation.

My personal views (and the reasons I didn't oppose this recommendation) were that CERN was pursuing a challenging programme, as well as being the preeminent exemplar of European cooperation in science. Moreover, the Americans had just abandoned their hubristic "SSC" project. This meant that CERN would, without any doubt, be the preeminent world centre for particle physics for the next 15 plus years: such a confident claim would *never* have been made previously.

So it would have seemed deeply perverse for the UK to "pull the plug" on CERN just at this juncture (and when, moreover, CERN had a British Director-General, and the prime scientific quest was for a particle, the "Higgs", named after a Scottish professor!).

Nonetheless, the consequent commitment (unfortunately denominated in Swiss Francs!) looms disproportionately large in PPARC's current budget. Our Government is right to seek further savings at CERN; also we must ensure that the extra money from Japan, the US and other countries that may affiliate to CERN is at least partly used to reduce the burden on the existing members.

Space Science

In most European countries, funding for ESA's space programmes (including space science) is additional to the normal science budget. This means that we in the UK have a dilemma; either we devote a disproportionate share of research council funds to space science, or we become uncompetitive with other countries. At the moment, we are in a specially unfortunate bind; having paid about £40 million per year towards ESA's mandatory scientific programme, PPARC doesn't have enough additional funds to cover the cost of instruments/experiments, with the result that we risk getting very poor value for money out of ESA.

It is obviously unsatisfactory that PPARC pays this massive "cover charge", but cannot afford enough involvement in instrument-building to ensure that we reap even as much scientific return as our European neighbours. We might as well withdraw from ESA if we can't participate properly—though such an eventuality would be unfortunate for space technology as well as for science (and for European collaboration generally).

In Europe, as in the US, space science rides along as a minor part of the overall programme—but often as a stimulus to innovation, not as a parasite. This means that space has to be considered in a broader context.

The total European space effort—ESA plus national programmes—is small compared to its counterpart in the US. Over there, the space effort, owing to superpower rivalry, ramped up to a much higher level. Europe has remained competitive by concentrating on certain areas (and, of course, by eschewing manned projects).

The sharp demarcation between ESA's mandatory science programme (charged to PPARC) and the various à la carte applications programmes (towards which DTI contributes, overall, a much larger sum) is unhelpful—particularly in environmental research where earth resources or meterological satellites can in principle yield a scientific return. Through our lack of a forcefully-argued co-ordinated positive policy, we in the UK have been less influential than we deserve to be, and have derived less benefit than we might have done from our overall spending on ESA. Effective co-ordination might actually be easier now that OST is embedded in DTI, with a single junior minister responsible for all space policy.

ASTRONOMY

The UK's contributions in astronomy have a breadth and quality which are probably unmatched by any other country of its size. We are fortunate to have achieved this in an era when the subject itself is experiencing a "golden age". Even cursory inspection of general journals such as *Science, New Scientist* or *Nature* shows the growing scope and liveliness of astronomy, and its strengthening interactions with other disciplines.

News of at least some of these successes, and the UK's contributions to them, has gratifyingly spread to a broad public; astronomy has (unlike some other high-profile sciences) a positive and non-threatening public image. Our involvement in this rapidly-advancing field thereby has a broader national value in stimulating general interest in scientific and technical matters—particularly among young people.

Ground-based astronomical research benefits enormously (like space research) from international partnerships, but these are relatively modest *ad hoc* collaborations, administered and prioritised at the research council level. Facilities aren't so large that they require quasi-permanent institutions like those needed in the two really big sciences—particle physics and space research. The total cost of our national observatories, including the overseas sites on Hawaii and La Palma, is about £15 million. (UK astronomers fortunately had the wisdom to avoid joining ESO, the European collaboration which is in some respects the ground-based counterpart of ESA).

The astonomical community in the UK includes scientists with a variety of expertise in physical science, instrumentation, etc. It is, like the particle physics community, knit together by the need to share national (or international) facilities. But a typical astronomical research project doesn't require a large group—the field (fortunately) isn't like particle physics where each paper has dozens of authors. Indeed, the national telescopes offer exceptional opportunities for individual young scientists to make a distinctively original contribution. (The term "big science" has misleading connotations when applied to astronomy).

Someone based in a small university can compete on equal terms for observing time on national telescopes, and thereby participate in frontier research. Indeed excellent work comes from numerous small universities and from at least three former polytechnics. It's no harder for these people to get to our overseas observing sites that it is for those who start from Cambridge or London.

This broad-based access depends on an effective infrastructure at the overseas sites, and at the Royal Obervatories (which remain important national assets): PPARC is already exploring alternative (and less cumbersome) administrative structures for the operation of these important national facilities. The ground-based programme in optical and infrared astronomy (which involves neither CERN nor ESA) is already, however, a relatively cost-effective element of PPARC's activities—and one whose "constituency", moreover, involves groups in at least 35 universities.

The former SERC deserves some credit for having facilitated the build-up of a strong "suite" of astronomical facilities, in the 1970s and 1980s. But technical improvements proceed apace. A new generation of larger telescopes (8-10 mirrors) is being developed world-wide. In addition, three technical advances enhance the efficiency of all telescopes: (i) new high-quantum-efficiency (up to 80 per cent) photon detectors; (ii) active and adaptive optics to sharpen images and compensate for atmospheric fluctuations; and (iii) optical fibre techniques for simultaneous multi-object spectroscopy. (The concurrent advances in computer power allow the higher resultant higher data-flow to be handled). It is crucial to our continued high astronomical standing that the UK participates actively in the next generation of innovation.

SCIENTIFIC PRIORITIES, AND RELATION TO PHYSICAL SCIENCES

At the small-grant level, peer review within PPARC seems basically satisfactory, having the same strengths and weaknesses as in the other sciences.

However major projects involve strategic considerations; when international partnerships are involved, there is inevitably an opportunistic element. Prioritising these choices, when funding constraints enjoin severe selectivity, is more complex and demanding than the peer-review of small grants. PPARC is evolving its own consultation procedures: I hope it will learn from US experience, where the NAS-NRC has a particularly fine record of setting long-term priorities not only within disciplines but (and this is more difficult!) across them.

But it's hard to motivate such exercises unless there is scope for a realistic range of choice. PPARC is actively seeking economies in all segments of its programme, in order to open up a "wedge" of funding for new projects; even so, budgetary constraints, coupled with ongoing commitments, allow very little freedom of action. The present deployment of funds is suboptimal, and will remain so as long as more international subscriptions consume more than half the total budget. PPARC cannot fulfil its mission effectively until a higher proportion of its budget can be directed to university groups, and innovative projects.

The criteria for judging our success (and, where necessary, readjusting the balance of the overall programme) should be:

(a) the impact and international competitiveness (and/or complementarity) of UK research achievements; and

(b) the broader "leavening" that such successes can offer by inspiring young people towards scientific careers, enhancing the quality of university training, and stimulating physics-based science and technology both in universities and in industry.

[There are widespread, and in my view well-based, concerns that the international competitiveness of the UK science base—traditionally one of our strengths—is in jeopardy. These concerns are felt even in biomedical areas (see for instance the article by Dr Bridget Ogilvie in the Science and Public Affairs (Winter 1995 issue)); but they are far more acute in physics-related sciences, where supplementation of public funds by foundations and industry is on a far more mearge scale.]

SUMMARY

For PPARC to fulfil its mission effectively:

(i) It must be recognised that a cost-effective programme requires the right balance between funds for central facilities and those needed to exploit them and foster innovative smaller-scale projects.

(ii) PPARC's major projects are inherently long-term, so efficient use of resources requires reasonably consistent forward projections.

(iii) The UK must seek to reduce the impact of the huge CERN subscription.

(iv) If we stay in ESA, we must evolve an effective co-ordinated strategy embracing all aspects of space science and technology.

(v) If the immediate budgetary "crunch" can be eased, a key challenge facing PPARC will be to develop a methodology for setting (and if necessary rebalancing) priorities across (rather than just within) the scientific fields it covers.

Examination of Witnesses

PROFESSOR J L CULHANE, Department of Space and Climate Physics, University College, London; PROFESSOR G E KALMUS, Particle Physics Department, Rutherford Appleton Laboratory; and PROFESSOR SIR MARTIN REES, Astronomer Royal, examined.

Chairman

1. As you are aware, gentlemen, we are taking evidence in the inquiry into PPARC and we will have a discussion with you. We have already had the privilege of one presentation across the road which one could say is already by PPARC, but we are wanting now to have further information before we make our visit in April to CERN itself and to ESA, so we have invited you here specifically with those projects in mind. Can I start off with a general question. How important are the disciplines funded by the PPARC in fostering enthusiasm for science as a whole? Can the person in the street be made more aware of what are the key issues in particle physics in such a way that they are not actually "baffled by science"? Who would like to speak in plain English and give a very brief answer?

(*Professor Kalmus*) Perhaps if it is particle physics, I should try and respond. I think it has been said in front of you here that it is actually quite difficult and I do not think we should underestimate it. Nevertheless, I believe it is important. We have here sitting behind us Professor Close who gave the Christmas lectures at the Royal Institution in 1993. That had a very large audience, I think, of 1.85 million. I think that audience shows that there is actually a way of talking about it and of there being a reasonable understanding. I do not know whether you want me to say a little bit about what we are doing. I think we are very aware of this difficulty. I know that Sir John Cadogan in his evidence said that the last thing he would ever do is to have particle physics explained by a particle physicist or indeed I think thermodynamics explained by a thermodynamicist. I am not sure that I agree with him. What I perhaps would agree with is that you have to pick your particle physicist rather carefully, but, nevertheless, I think it is possible and, just as perhaps a quick reminder, the things that were considered to be on the sort of edge of human understanding in the 1920s, quantum mechanics, are now taught in every undergraduate course and so there are tens of thousands of people who now understand the concept, so it takes a while.

Dr Jones

2. Just because you are taught does not mean you understand!

(*Professor Kalmus*) Well, they have more than a passing understanding, I believe.

Dr Bray: Is it not the problem that quantum mechanics is really extremely difficult to get the grasp of and you have only to read the literature and the possible implications of quantum mechanics written by a particle physicist to see why the public are perplexed?

Chairman

3. Except for your work, I am sure!

(*Professor Kalmus*) Thank you! I take your point, but can I say that of course we are very keen on the public understanding of science, but of course it is also important to say that quantum mechanics in itself in fact underpins some of our greatest industries now, the semi-conductor industry, the laser industry, so yes, of course public understanding, but it is not the only reason we are doing this work.

Dr Bray

4. Is it not best to come clean and say that really it is not necessary for the public to understand quantum mechanics to use a television set?

(*Professor Kalmus*) I do not believe that it is necessary for the public to understand in detail quantum mechanics. I do think that one should be able to explain what it is about, the fact that things are probabilistic instead of certain. I think that is something that one can explain. It may not be perfectly understood, but I think it is of importance.

Sir Trevor Skeet

5. Professor Kalmus, I wonder whether you would dilate on what you have stated just a moment ago about particle physics. The contribution to society over the years has been enormous in networking, medical physics and in the founding of the atomic age. The public do not understand this and they cannot see the reason for the continuance of this. Would you explain what achievements have accrued to date?

(*Professor Kalmus*) Well, I hope that what you will see is that the time-lag between, if you like, the scientific understanding and it becoming a useful role in society is of the order of 50 years, so I think we are talking about a long time. Coming back to the previous question, I believe it is our duty to let people know that much of the modern world and modern technology is indeed underpinned by the kind of things that our forefathers did 50, 60, 70 years ago and that is something that, as you rightly say, is not understood by the public and we ought to be doing it and, speaking for myself, I am doing it.

Dr Williams

6. Could I say that on the public understanding, I have had great problems here. Astronomy I understand reasonably and space research I have some concept of and I can see its usefulness, but particle physics, despite the fact that I once did a degree in chemistry, I feel it is profoundly difficult to understand even the outline concepts, but on its applications, again I find that it fails on its applications. When I think of my contemporaries, say, 20 or 30 years ago who spent their lifetimes in

[Dr Williams *Cont*]
particle physics, I do ask myself, "What have they achieved from that?" We have just finished an inquiry into genetics and looking at genetics is a fascinating field 20 or 30 years ago and today not only is it very important academically, but it is very important medically, socially and potentially extremely important within the next century. I just cannot see that at all with particle physics and, despite my colleague Sir Trevor Skeet's earlier question to you, I really cannot find those applications and why it is useful?

(*Professor Kalmus*) A very quick answer is that I think I would like just to quote Rutherford who said that he could see no possible application to splitting the atom, nuclear fission, when he did and he was actually a rather wise man, apart from being a good scientist. I think it is very difficult for us. If we knew the answers, we would not be doing the work to some extent. We are talking about research and not development.

Chairman: I think that is the key point.

Sir Gerard Vaughan

7. Can we press you just a little bit more on this? You mentioned just now the course of lectures. That was carried out, did you say, two years ago?

(*Professor Kalmus*) It was Christmas 1993, I believe.

8. Have you got any other programmes in mind either in the future, if not actually going on now?

(*Professor Kalmus*) Yes, indeed. In the SET 1996 there are a series of lectures on particle physics again and I am sure there are similar lectures on astronomy. We have programmes at the Rutherford Laboratory where I am for local schoolchildren, for local school teachers.

9. How successful are those?

(*Professor Kalmus*) It is very difficult to gather this information. The schools I go and talk to, there are lots of questions, lots of enthusiasm on how does it actually result in people's future lives. It is very difficult. I did come across somebody who told me that, and this is anecdotal, they went into physics at university because they heard a Frank Close lecture. I have never heard anybody say the same thing about any of my lectures, but maybe that will come one day!

Mr Thompson

10. I do want to come in really on the question of public understanding which is what we have been talking about on and off in the last ten minutes. Do you agree with me that it is perhaps wrong for us to be moving towards a conclusion that all these things are too difficult for the public to understand? Stephen Hawking of course, very well known, writing about space science and other issues, his books are probably among the most popular by any standards, including those of popular novelists, showing that there is public enthusiasm and appreciation of difficult topics. Going right back to when I was a boy, I can remember people like George Gamow writing his *Mr Tompkins in Wonderland* books and so on. Once again I declare a prejudice which is that I am a physicist by training which is perhaps why I am slightly off-beam here, but seriously, do you agree with me that it is wrong to say that there is not public enthusiasm for this difficult topic? Do you see what I am driving at? I realise we are short of time, but could you just put the record straight because I was not happy about the drift of the discussion?

(*Professor Kalmus*) I think that it depends very much on what you call "the public", but there are a large number of people who, for instance, go to the British Association and who attend particle physics lectures. There is great enthusiasm around the country. University physics departments hold open days. In Scotland, in particular in Edinburgh, they have a science festival and it is absolutely swamped with young people.

Chairman

11. I think we will hold that particular section and move on, if we may.

(*Professor Sir Martin Rees*) Could I just say a word, Chairman? I am the Chairman of the Public Understanding Committee of PPARC and I just thought I would say essentially that I share the views expressed by the Members. I think PPARC accepts that it has a special obligation and a special opportunity to do all it can to foster public understanding. It has a special obligation because, as we are well aware, its activities have less direct, short-term applications than other research councils, and a special opportunity because, as we have just heard, there is very wide public enthusiasm for these subjects. I think we do have to accept that some areas within PPARC are more readily popularised than others and, as someone who is primarily in astrophysics and space science, I accept that my colleagues in particle physics do have a harder time. I think they try at least as hard as we do, but they do have a harder time because of the abstract nature of particle physics, because discoveries come in a few big ones rather than lots of smaller ones and for a number of other reasons. We have to accept that some areas are more readily popularised than others and I think it would be a pity if we biased our budget, as it were, too much on those criteria. I think we ought to be thinking more about which of PPARC's activities will figure large when the history of the science in this period is written.

Mr Miller

12. PPARC has said that this is a time when major breakthroughs are in reach in each of the disciplines supported by PPARC. Is this not really a natural reflection of the enthusiasm of a bunch of a very good scientists or is it really just the natural state of science?

(*Professor Sir Martin Rees*) It is the natural state of all sciences that are in a healthy state and I would certainly say that the PPARC sciences are in a healthy state for that reason. One could certainly point to no diminution, rather the reverse, in the rate of new discoveries. As the frontiers have advanced, their periphery has got longer and the rate of new discoveries has increased, I think there would be a fairly wide consensus that among the physical sciences, it is the PPARC areas which are really

[**Mr Miller** *Cont*]

emerging at this moment and we see this not only in the intrinsic science, but in the appeal they have to students and potential students. The health of physics as a subject in this country in our universities, depends very greatly on the activities of the scientists working in the areas that PPARC is concerned to foster. They are the lively ones and they are the ones that inspire young people.

13. I do not know what these major breakthroughs are going to be or indeed what their significance is going to be. For example, if the LHC creates or finds the Higgs boson, will the really important thing be the confirmation that it exists or the quantitative information about it?

(*Professor Sir Martin Rees*) That is for Professor Kalmus!

(*Professor Kalmus*) I suppose the political answer would be yes, both, or something. It is one model. It is probably the main game in town, the Higgs mechanism, and it is not the only way, but it is the way that seems to be the most natural for explaining mass. What is its significance? Well, the first thing is that there is not a single Higgs mechanism, but there is a sort of spectrum of things, so you would like to know really what it is that happens and is there a single Higgs or is there a series of Higgs particles. That is important. Unfortunately, really without knowing something about the Higgs, something about its properties, something about its mass and so on, one really cannot get very much further. Once one knows that, I think that new lines of investigation will open up. Just very quickly if I can say something about the importance of Higgs if it is found or if it is not found, whatever other mechanism there is for mass generation, if you think of Einstein's formula, his special relativity formula, $E = mc^2$, m is mass and we do not really know what it is that generates mass. So it is understanding something, it is very difficult for me to say, "Yes, this is going to have some tremendous importance in 50 years' time", but the fact that there is an understanding of a very important concept in the world seems to me to be rather important.

Mr Miller: But we have now arrived at a position where a press article which was circulated in the Committee the other day suggested, for example, that quarks are not fundamental particles after all. Is there, therefore, a danger that all this investigation into basic science will just go on into infinity and, if that is the case, is it also the case for all of the other disciplines supported by PPARC?

Chairman

14. I am bound to say that it came as somewhat of a shock to me, because I was wholly persuaded by Professor Close that they were absolutely fundamentally important ten days ago, but now I am worried.

(*Professor Kalmus*) Would you like me to answer? I would be happy to. The first thing is that you should not believe everything you read in the newspapers.

Mr Miller

15. The whole Committee would agree with that!

(*Professor Kalmus*) Can I say that I have actually read this article and this is a case where a paper has actually appeared in the scientific literature and I have read that paper and the authors did not claim, what the newspapers claim. What they have found is an effect which can be explained which at present is not easily explained and one possible explanation is this one of sub-structure, but there are other possible explanations. So the first thing is do not believe everything you read and the second is, well, say it did happen and say it was true. The first thing is that probably in order to show whether it is true or not, you need the LHC and they probably cannot do it at the Fermi Laboratory in the States, they do not have the energy reach and they do not have the statistical reach that is needed. But say it happened. Well, my answer to that is that I think that when we have peeled away another layer of the onion, another layer of understanding, what we found in the past is a simplification in general, our understanding has allowed us to have a simpler picture. At present there are really only four particles of matter in the universe. There is an up-quark, a down-quark, an electron and its neutral partner, the neutrino. Somehow or another, this has been xeroxed three times. We do not know why that is, but the universe about us is really only made up of these four fundamental particles. Now, that, I believe, is an enormous simplification compared to the things that you see around you, even compared to the 92 naturally occurring elements.

Mr Batiste

16. In the areas funded by PPARC, in which, would you say, does the UK possess particular strengths and in which are we particularly weak?

(*Professor Culhane*) Could I perhaps comment briefly there? I would follow Professor Rees' comments that the periphery of investigation is expanding continually. I believe or I suppose that access to space has enormously enhanced facets of astronomy and technically the UK has pioneered and continues to lead in parts of the spectrum. For example, X-ray astronomy, we have major strengths there and we are developing them in infra-red and you will probably have read today of the discovery of water molecules in an exploding star, so the expansion of astronomy throughout the spectrum and the use of all the spectral ranges to advance on a broad canvas, this is an area of very considerable strength. Moving closer to earth, I believe the influence, the understanding of the influence of the sun on the earth, to begin with, but also the solar system, I think there are very great strengths there. These strengths, I might say, in addition to being fundamental, and the interior of the sun provides us with a useful link to the particle work of George and his colleagues, namely the neutrino problem, it is also investigable by astrophysical techniques, but in addition to the fundamental issues here, the role of the sun in its influence on earth, the outflowing of the solar wind, its interactions with earth, these have strongly practical impacts, the disruption of power

[Mr Batiste *Cont*]

supplies due to magnetic storms, so there is a coupling and these are indeed areas in which we have strengths.

(*Professor Sir Martin Rees*) Could I supplement that because you might have got the impression that we are good at everything, *et cetera*, but we are good at a wide range of areas primarily because we are involved in international partnerships. Clearly in a science that involves expensive facilities, we cannot do everything ourselves and PPARC essentially does almost everything in international partnerships. We are only able to have the fairly broad coverage through being involved with and plugged into international partnerships where our expertise is appreciated, and that is two of the points that Professor Culhane mentioned, but I would just like to emphasise that we clearly cannot do everything. One area where we are not as strong as other countries is in planetary science and planetary physics. That is something which is an important part of space science which in the United States attracts great publicity and we have never been major players in that, sadly, but that is one of the things that even in collaboration we have never made a big effort to succeed in.

17. If one then takes this a stage further, and there are some questions which will be asked of you later, but if we are talking about a 50-year lead time for the basic research of this science before we get practical results and trying to translate this into terms which will be meaningful for our society, if you come across discoveries they are probably almost immediately in basic science and disseminated very rapidly and there certainly needs to be a basic level of application and infrastructure in the science base to be able to exploit that, but is it absolutely essential for us to be necessarily at the sharp end of this basic research where the costs are so very expensive in that the research, if it continues to take place, will be available to our scientists in 10, 15 or 20 years' time anyway?

(*Professor Sir Martin Rees*) To appreciate the science, you have to have a body of expertise available, but perhaps one could answer your questions, sir, by a sort of thought experiment. I think no one believes we are going completely to stop doing all these sciences, but what we should consider is what the future projections should be. The reason that many of us are enthusiastic and believe that the sciences involved in PPARC's activities are important is that we feel there is a great deal of science to be achieved that will have a great effect not only in its own right, but through a spin-off into the university community, the quality of higher education and all the rest of it if we maintain our investment at past levels. On the other hand, if we were to be faced with a policy decision that the budget would be declining in future, then the one thing we would be sure of is that the actual cost-effectiveness with which we spend that budget will go down. In other words, if there was to be a 10 per cent cut, then the amount of world-class science that we would get out would drop by a lot more than 10 per cent; we have to decide whether we are to be in these fields at all and once we are in them, then we have to maintain a certain level of activity in order to be welcome collaborators in the respect of our international partners.

18. So you are talking about a critical mass of investment?

(*Professor Sir Martin Rees*) It is a critical mass, yes, and if we have a declining budget, then given overhead costs and commitments, et cetera, there is a risk that then the cost-effectiveness goes down.

19. Do you regard the current level of spending at least in the PPARC areas as sustaining that critical mass?

(*Professor Sir Martin Rees*) No, and I am sure you have many more questions about this, but I think one of the concerns that we have in PPARC is that the present investment level is not maintaining what we have achieved at the moment due to investment in the 1970s and the 1980s because, as everyone knows, the share of the science budget in big sciences has gone down and we feel we are benefiting from the investment of the 1970s and the 1980s.

Chairman

20. But not replenishing your stock?

(*Professor Sir Martin Rees*) Yes.

Mr Thompson

21. I want to preface my question because the question is going to be about the changeover from the Science and Engineering Research Council to PPARC and I really must link that to something else. We have just heard some discussion about the investment level being too low and the implication from some of the questioning is that perhaps it should be decreasing because other people can do this. My preliminary question is: is it not a measure of the culture of a nation the amount of enthusiasm it puts into its science, and the same thing can be said about the arts where if we were having a discussion about the National Lottery or something else, we would be talking about the arts, but we are not, we are talking about science, so is there not a drive to increase the expenditure on activities in pure science which has got nothing to do with some of the more financial arguments that we are hearing? Now, I want to couple that with the main question which is that as we change from the Science and Engineering Research Council to PPARC, or have changed, has that altered the situation, the perception of the problem we are already discussing, has it altered the nature of the decisions which have to be taken and is it going to make it easier or more difficult for policy-makers to operate in this area? Now, I do want a response to my first question because it does seem to be underlying the discussion all the way through so far. Is science important in its own right? I am not supposed to have a view on that, Chairman, but never mind, or are we just adding up something?

(*Professor Culhane*) In response to the first, could I comment that indeed the cultural importance of science for an advanced technological society such as the United Kingdom I think goes without saying. I would take the extreme point as *reductio ad absurdum*. We could of course drop everything now absurdly and retreat from the front-line over a five-year period or something of that sort by remaining at a level commensurate with the success we have been achieving in the past decade and I believe we can

[**Mr Thompson** *Cont*]
demonstrate an ability to go on doing this cost-effectively, but I do not believe one should necessarily look at these in absolute terms. One can subject them to differential terms, and this comes rather to your second question, that from some perspectives within PPARC, because of the international subscription difficulties, and we will no doubt come to those later, we are now beginning to confront a sharp differential, that the resource available to support the work we do internationally appeared within the term of the existence of PPARC to be dropping by something of the order of factor two. Now, that sharp differential and the speed with which it is projected to happen is clearly very disruptive. Finally, to come to the essence of your last part, it is, I believe, unreasonable to say that this is in any sense the fault of PPARC. I believe a progressive situation was in train over the past decade in which the international subscription had been progressively increasing. They have now begun to squeeze the so-called domestic funding to the point where we now confront a new disaster, I think, though "disaster" may be too strong, but we are certainly looking at an incipient reality.

Chairman

22. But, Professor, there is an element here surely of failure to persuade those that the priority to be given should be heightened because clearly that is a consequence, is it not, of not gaining the priority?

(*Professor Culhane*) Well, it is a question also of timing. The difficult problem which I speak of is of comparatively recent vintage and I do not believe it is fully understood that the so-called domestic support of the international programmes goes hand in hand with the subscriptions and while it is essential, and we come to this later, to squeeze the international agencies to promote greater efficiencies, if in the short term we do that simply by allowing the entire budget to collapse, then this is a *non sequitur*.

Mrs Campbell

23. I am concerned about the results of this on science and really I am looking for a justification from you for carrying out and putting an extensive amount of money into basic science in this country. The problem is I think that the results of basic science are very easily disseminated all around the world. I am not sure that the understanding is always disseminated quite so rapidly, but do you feel that there is an advantage in being involved in basic science in this way? Obviously you do and I am asking you to confirm that.

(*Professor Sir Martin Rees*) I think you phrased it in terms of basic science and it is right to think of all basic science first. Clearly we support this, as Mr Thompson said, partly for cultural reasons, but of course we do not support it solely for that reason, but we support it for its underpinning of technology and the higher education system and all kinds of other reasons. It is all those considerations that determine the funding level for basic science in general and that of course means all the research councils. Now, there is then of course the issue of how the funding is deployed along the frontier, as it were, among the different research councils, the different basic sciences. What PPARC has to do is to reaffirm the case that the basic sciences in which it is involved do justify a share of the cake, which has perhaps diminished a bit too much over the last 20 years because there has been quite a drastic decline in the proportion of the basic science vote, as it were, going to these areas. I think 20 years ago the CERN subscription was in real terms even higher than now and at that time almost as much was being spent on the domestic part of the programme, so there has been quite a big cut, almost a factor of two, and if you think of how to deploy intellectual effort for physics overall, then there is a case for, if anything, slightly reversing the trend because of the timeliness of the PPARC areas, but one has to argue the political case for basic science as a whole It is to some extent a scientific debate about where the timely areas are.

(*Professor Kalmus*) Could I just add something? Britain has had a long and proud history in basic science and that is particularly true in the two areas that PPARC represents. I believe that this has had an impact on the vision that the world has of Britain as a civilised nation actually. I think it would be not understood internationally if we were just to withdraw from one of these and say, "Well, you know, 200 years of research and we are going to give this up", and I think it will be viewed in some ways as an act of barbarism and so I think that there is that dimension. One can say that that is not really a very good argument, but I do believe it is an argument. It is the way that people see us. Can I then give you one piece of information. In particle physics the domestic programme 20 years ago was £65 million in 1995 figures, ten years ago it was £31 million and in 1995 it was £21 million, so we have gone down a factor of three in real terms over 20 years. We have gone down in ten years to two-thirds, whereas the CERN subscription has been roughly level. So this decrease has really been, in our case, disastrous. Just to give you one final figure, if we compare our expenditure with France, Italy and Germany, they spent 3.2 times as much in France, 4.5 times as much in Italy and 3.2 times as much in Germany.

Chairman

24. On the same science?

(*Professor Kalmus*) On domestic expenditure on particle physics in those countries, so there are these huge factors already.

Chairman: Let us turn now to the international issue of subscription.

Sir Gerard Vaughan

25. Still on funding and this time on the subscriptions, a few years ago there was a great outcry about the arrangements for international subscriptions, and quite justified because it was a great handicap, I believe. Since then, there have been some changes made. What is the position now from your point of view?

(*Professor Kalmus*) Perhaps I can tell you about CERN. Some time ago the person who is now the Director-General of CERN, Chris Llewllyn Smith,

[Sir Gerard Vaughan *Cont*]
who was at that time a professor in Oxford, found a new formula for the CERN subscription and how that should be estimated for the future and that gave a degree of stability against currency fluctuations. It turned out unfortunately that it was not robust enough to deal with cases where all currencies declined against the Swiss franc, not just some declined and some got stronger, and the position we have seen over the last two years has been that basically all currencies have declined against the Swiss franc and in the case of Britain by 27 per cent in two years, so the answer is that in Swiss francs over the last two years our contribution has not changed effectively, but in pounds it has gone up by 27 per cent over the two years or so.

Sir Trevor Skeet

26. Is there not an additional factor here, that most of the expenditure on CERN is in Switzerland?
(*Professor Kalmus*) Yes.

27. And, therefore, we have to pay twice over. The other thing is that our GNP has also gone up in the last two or three years which has created a further complication for the formula.
(*Professor Kalmus*) Yes, it turns out that the GNP has gone up by about 4 per cent or something, yes, but compared to 27, it is still not the major effect.

Chairman

28. Professor Culhane, can I bring you into this discussion now? You have said that there is no viable alternative to UK space science other than to be a partner in ESA. Does the ESA mandatory science programme match approximately the interests of the UK space science community?
(*Professor Culhane*) Yes, I believe it does and I think that is demonstrated by the leading role played in it by individual UK scientists and institutes. One can measure the success we have had in terms of the number of leading roles, the number of principal investigatorships, the number of ideas we have put forward for future programmes. On measures of this sort, we do lead within Europe. However, our subscription does remain connected to the gross national product. We suffer some of the difficulties that Professor Kalmus has mentioned, but, nevertheless, the programme, I believe, is well matched. I think a further, very important point is a programme whose match we can influence. We are members and we have a voice. It is up to us how effectively we use that voice, and I believe in the past we have used it effectively, to get the kind of programme which suits the skills, the interests of our own practitioners. I think that is in distinction to the so-called bilateral programmes. These are extremely good opportunistic avenues to follow, but over the long term I do not believe they are viable because we are at the whim and the mercy, if you will, of the other nations who are leading these programmes. We can from time to time achieve opportunistic coups and we have done so on several occasions, but I believe to rely solely on this would be a mistake and we would lose our way.

29. Are you happy with this, Sir Martin?
(*Professor Sir Martin Rees*) Yes, I would like to emphasise the point that in partnerships of this kind our aim should be to get more than our pro rata share of the scientific action. That is our obligation and our wish in these things.

30. I would never dream you went for less!
(*Professor Sir Martin Rees*) Indeed, and I think we have in fact succeeded in ESA in doing that.

Mr Batiste

31. I suppose the difference between ESA and CERN is a very high proportion of our mandatory contribution to ESA goes directly back into the UK into science programmes at home, whereas our contribution in CERN gets swallowed up in the infrastructure programme and a relatively small part of it actually comes back to us at home and, as a consequence, we are probably reaching a point in relation to CERN where we are just not getting the benefit of our subscription because there is not enough coming back to us.
(*Professor Culhane*) The situation is a bit more difficult than that. It is true, of course, that this principle of return does operate in our favour, as it does in favour of everybody else, but the difficulty that the science and space disciplines face is that the mandatory science programme is about 12 per cent by volume of the entire activity of ESA. In the manner in which we conduct the programme we have somewhat less influence than our colleagues would in CERN. The search for efficiencies, for ways of doing things which are appropriate for science, is frequently checked.

32. My comment is about the mandatory space programme where we do have a substantial share because it is fixed.
(*Professor Culhane*) Indeed, but the conduct of it takes on the character of the much larger agencies since by volume it is only 12 per cent of the volume. You are right in that there is a return.

Sir Trevor Skeet

33. Professor Culhane, when you were in SERC you seemed to have a clearer road ahead but now the Director General of the Research Council takes over he is in a rather absolute position and he does all the negotiations about ESA. Can he not dictate to you what he wants?
(*Professor Culhane*) I guess he can in principle dictate to us. The problem may be rather more that he is unable to dictate to our partners and indeed the manner of addressing the partners, whilst it must be robust and must always seek to advance our self-interest, must be done delicately and—

Chairman

34. With finesse!
(*Professor Culhane*) Even finesse.

Dr Williams

35. I tend to think of particle physics as being completely dependent on CERN or that CERN dominates particle physics but then we look at the work done in particle physics in Britain's universities, how much of it is CERN dependent and is there a large useful chunk of work that can be done that is unrelated to CERN?

(*Professor Kalmus*) I can give you a reply about CERN related. Probably something like three-quarters of the work is now CERN related, perhaps a little bit less at present. We believe that by the LHC era, the middle of 2004/2005, that number will be about 75 per cent, perhaps 80 per cent. So we believe that 20 per cent of our programme, as I think with space, should be special opportunities, special very focused experiments that can be done elsewhere, in particular down deep mines and things of that kind. There are now quite a few facilities. There are very specific questions that these experiments can answer. It is like in horse racing always betting on the outsiders, at a certain point you go bankrupt. I think one has to be clear and what is clear I think to us and to the rest of the world community is that the most probable place for breakthroughs is going to be the LHC. We do not know what they will be but it has all the characteristics of a place where new discoveries will be made.

36. Could I ask in relation to labour intensive versus capital intensive, the non-CERN part, does it employ or train more scientists per million spent than the CERN part?

(*Professor Kalmus*) I do not think there is a great difference in fact.

Dr Bray

37. Are there other ways of achieving high energy intensities apart from particle accelerating?

(*Professor Kalmus*) The answer is not at present. There have been attempts, and there continue to be attempts, to find new mechanisms, mechanisms that are much cheaper, which take up less real estate, you do not have to have 27 km long tunnels and so on, but they have all failed up until now. There are still some ideas. One has to be aware however that there are two parameters, one is the energy and the other is the intensity. It turns out that these machines that we require have a beam energy, the total power in the beam is hundreds of kilowatts or megawatts. It is not the kind of thing you are ever going to be able to do on a bench top. We are talking about large scale electrical engineering. I believe that in the long-term future one may find a new idea and it may cut down the cost but one is not going to find something that fits into this room rather than being down a big tunnel at CERN.

38. Could you describe specifically the laser beam wave experiment at CERN?

(*Professor Kalmus*) Not terribly specifically. It is due to interference between two lasers. What you have in a laser is a very intense electric field that is set up but it is over very small distances. They are really uncontrolled at present in any sort of way. What has been achieved, and I can tell you the best result so far has come from the Rutherford Laboratory and in fact there are groups from America that are coming to use our lasers because they are most suited for this, has been 30 MeV but it can hardly be called a beam, only a few individual particles. I think this is the kind of thing that one should continue studying. I think there are chances for success, as with some previous attempts like electron ring accelerators and things of this sort, but there are formidable problems.

39. This energy intensity is obtained in the space of about 5mm, as I understand it.

(*Professor Kalmus*) Yes, it is a few millimetres.

40. That would have to be extrapolated to about ten metres to get results that would interest particle physicists today?

(*Professor Kalmus*) Not the sorts of energies that we really want, which are TeV energies, it is much longer than that. The scale up from 5mm to metres is a factor of a few hundred but we really need to go more than that to a few thousand.

41. How long do you need?

(*Professor Kalmus*) I do not think there is any way you can get continuous metres. You may be able to get very small bits but scattered. It is really far, far too early.

42. Exactly so. Would you not expect that?

(*Professor Kalmus*) Yes.

43. If you compare the amount of money put into the development of the beat wave experiments by comparison with the amount of money put into particle accelerators?

(*Professor Kalmus*) Really I think that one has to be careful. One does not always make progress by throwing money at things. The beat wave at present, yes some more money would be useful but pouring in huge sums of money would probably not be useful.

44. But, you see the particle beam accelerator is basically the idea of one man and it becomes the dogma of a whole branch of science and the young students have to conform to that if they want a career. If you dissipate that, if you open it up to dozens of projects, you vastly increase the scope for genuine discovery and inventiveness, do you not, in human terms?

(*Professor Kalmus*) There are two things, one is accelerator technology and the other is particle physics. The accelerator is a tool for us, it is not an end in itself. If you are saying is it useful to do research into accelerator technology, the answer is yes it is, and some is being done, very little in this country but if we had more money we certainly would like to do more. If you are asking is it possible in the next 20 years to think about this technology for forwarding our understanding in particle physics I think I would be fairly safe in saying this would not be a way within the next 20 years of doing that.

45. Might we not have a situation where there is a limit, and Professor Kalmus says there is a limit, and we will not be able to go on building this? When that limit comes it is not just a physical limit of 8,000 miles per annum, it is a socio-economic and scientific limit.

(*Professor Kalmus*) I agree entirely. It may well be that the current technology that we are using, the LHC, is at that point. If we wish to go further than that we are going to have to develop the technology. Could I remind you that there are two ways, one is

[**Dr Bray** *Cont*]

radically new ideas and the other is what has happened in recording media, for instance, in computers. Twenty years ago, 15 years ago, ten years ago even, everybody was betting that in ten years' time, in other words now, optical recording would be what was used. It was obvious that the wave length of light was much shorter than the grain size that you had on your magnetic materials and so on and it was obviously going to be but it has not happened. It has not happened because the industry that is involved in the magnetic technology has just improved enormously its product, much faster than the new things that have come in. The same thing happened some 25 years ago when I was in California when there was a great enthusiasm for steam cars again, modern steam cars, that they should be better, they should have better thermodynamic efficiencies and so on, that was going to be the car of the future, but the internal combustion engine has just improved again out of all proportion. It is possible that the way forward for accelerators, as it has been in the last ten years, is just conventional but getting better and better and better.

46. If you go to Ricardo Engineering, who are involved in absolutely the best engine research in the world, they will show you designs which are not straightforward internal combustion engines at all but which are combinations of turbo generators and battery. You are not getting that information in particle physics, are you?

(*Professor Kalmus*) Yes, you are. You are using super conducting cavities in different modes. There are all sorts of new things coming along that really are making considerable changes.

Chairman: I think the lecture will resume with the British Association shortly!

Mr Batiste

47. Can I ask one question going back a little bit. You were saying that the problem was Swiss francs in terms of costs and so forth, but was there any technical reason why the LHC had to be built in Switzerland?

(*Professor Kalmus*) Yes, I am afraid so. There is a 27 km tunnel that is already—

48. It is just the extent of that tunnel?

(*Professor Kalmus*) It is the tunnel and the injectors. You see, with a machine like this you do not start from zero and then go all the way to this 14 TeV, you have a series of pre-injectors.

49. I do not need to know the technical reason but there is a technical reason there?

(*Professor Kalmus*) Indeed.

Chairman

50. We shall see it.

(*Professor Kalmus*) It would have cost something like probably two and a half times as much on a greenfield site.

Mr Thompson

51. Moving on to ground-based astronomy, is there a better balance between international and domestic expenditure in ground-based astronomy than in space or particle physics?

(*Professor Sir Martin Rees*) Let me say I am embarrassed to be the pundit on ground-based astronomy because I am not a specialist on ground-based astronomy in the sense that my colleagues are specialists in the other areas.

Chairman

52. Just pretend you are for the moment.

(*Professor Sir Martin Rees*) To answer your question, I think our ground-based astronomy programme is again largely international. That is slightly less true of the radio band, but the other bands are largely international. The difference is these are, as it were, ad hoc international collaborations which are not above the level of PPARC, they are not international treaties on the level of ESA and CERN. For that reason they have, I think, proved rather more flexible and have served us well in general. As far as the balance is concerned, again there are the same concerns as in other areas to make sure that equipment remains competitive. To give you one example: we have had new four metre telescopes, a new one came into operation in the mid-1980s, and I saw some figures recently showing that the citations for UK papers compared to our competitors rose quite steeply in the field of astronomy at the time those telescopes came on line. There are now further technical developments and we have got to make sure we remain on board in this next generation of telescopes. We are participants in something called the Gemini Project, which is a pair of large telescopes, where we are involved with five other countries, the United States being the dominant partner and four others. This is the way we will get into the era of large telescopes. What we have to do is to ensure we continue our tradition of clever and innovative instrumentation to fit on them. One thing that came on line just three or four months ago was a new gadget fitted on the Anglo-Australian four metre telescope that much enlarges the field of view and allows optical fibres to be used to take 400 spectres simultaneously. That is a vast improvement. That is a prototype of the kind of equipment one would like to see installed on the next generation of telescopes. We have to make sure that we can provide the funding that is needed to provide instruments like that in the next generation. I think the short answer to your question is that the ground-based astronomy programme is less monolithic and therefore is slightly more under our control than the large partnerships involved in space and particle physics.

Mr Thompson

53. Has the participation in these projects helped or hindered our programmes to support innovative and small projects?

(*Professor Sir Martin Rees*) I think we have got to be in these international projects in order to have world class instruments. We have telescopes on the Canary Islands, and in Hawaii. We will soon have a

[**Mr Thompson** *Cont*]
share of one in Chile and I think it would not be feasible for us with our resources to have remained in this subject unless we had been in international partnership. The decision we made on ground-based astronomy about 20 or more years ago was not to join our European partners in something called the European Southern Observatory which was a large consortium of the main European countries. I think in retrospect we were wise instead to have developed ad hoc collaboration and I think it proved more cost effective. We certainly cannot manage without international partnership. We could not afford one of these telescopes ourselves.

Chairman: Can we turn to departmental budgets.

Mrs Campbell

54. The international subscriptions will largely determine of course the division of funds between the subject areas. I wonder if you feel that, supposing we did have a choice, we have got that division of funds right?

(*Professor Sir Martin Rees*) The PPARC Council certainly formed the view that its top priority was to get to a stage where the two international subscriptions were below 50 per cent of the total budget. They are now well above that and that is part of the problem for our short-term planning. I think we are always going to be paying quite a big fraction of this figure in our subscriptions, and we indeed want to because clearly the science is international. The main problem is that there have to be the complementary funds for exploiting those subscriptions. Also, there must be something left over in order for us to do innovative instruments. Professor Kalmus has mentioned that you do special experiments, high risk experiments, betting on outsiders as it were, and in the astronomy based area there are also experiments of that kind which we would dearly like to do which could be world beaters which cost £2 million to £4 million, that sort of range, and we want to be able to afford them.

Mrs Campbell: Forgive me for interrupting you but the point of my question really was whether we have got the division right between astronomy and particle physics?

Chairman: Space astronomy.

Mrs Campbell

55. To a large extent that was determined by international subscriptions but have we got it right?

(*Professor Sir Martin Rees*) I think the answer to youı question is that that balance is a legacy of decisions going back 40 years.

56. But is that right?

(*Professor Sir Martin Rees*) We were faced with a decision in 1994 that we either join the LHC, which had that very high price tag, or we abandon the subject and as I have mentioned in my written evidence it seemed to me that although it was clear it was going to be a very large commitment it would have been perverse for us to drop out of particle physics just at the time when, as never before, you could be confident that CERN would be the world centre for the subject. We are fairly constrained by the legacy of history.

Chairman

57. Was it a correct decision?

(*Professor Sir Martin Rees*) It was a decision that I supported at the time and still would.

Dr Jones

58. Could I just pick up some things that you have already said. Is there anything inherently different in ground-based astronomy from the other areas of PPARC's work which makes it easier to have these ad hoc arrangements than the treaty and collaborations because there is a quote from you that thank goodness we did not join ESO, the equivalent of ESA, for space astronomy?

(*Professor Sir Martin Rees*) I think the simplest answer I can give is that it is not quite so expensive. A typical space project, ESA project, is measured in hundreds of millions of whatever currency, of pounds, whereas even a really large telescope is measured in eight figures and not nine. The largest single item of equipment which one needs for ground-based astronomy is the kind of thing which we maybe cannot afford ourselves but with international partners we have been able to afford. I think the simple answer is that it is not quite such a big science in an international sense as a space project.

59. We have got the message, I think, that you feel current investment is not going to be sufficient to sustain the science base but is it worse for some disciplines than for others?

(*Professor Sir Martin Rees*) There is a special issue which perhaps we will talk about later which is the Atlas experiment for the LHC which requires a very large lump of expenditure over the next few years which is a difficult item to fund. I think there are two things for which one has to make sure the funds are available. One is to update the existing equipment and make sure that something like a telescope does fulfil its potential very long life of several decades by being updated and modernised. The other is to always have enough for the opportunist experiment which a university group or small consortium of universities wants to do. I think that is the reason why it is important to keep the wedge open.

60. I am not sure that my question was actually addressed. Are there some areas of your work where this is not a problem?

(*Professor Culhane*) Might I comment on the space aspect which is one where indeed it is a problem. The programme operating within ESA, the so-called Horizon 2000, consists of a series of scientific missions, scientific opportunities, and these occur discretely in time, they happen on a certain date and, as has been the case in the recent difficulties with the so-called INTEGRAL Mission, in the absence of appropriate domestic funding we have simply not been able to make a substantial bid to be involved even though many people have said much of the intellectual effort to bring that mission about came from people in the United Kingdom. The effect of reduction in the matching domestic funds has been to force us to drop out of the INTEGRAL Mission. This regrettably will not come back so we have missed a boat, a very specific boat. Again, it is hard

[Dr Jones *Cont*]

to set figures on it but an enhancement of about factor two in the available funding for domestic support of ESA, let us say of the order of £5 million annually to match to the restricted amount available now, would permit us to partake of that particular opportunity. The risk is that we miss the boat completely because the programme marches at a particular time.

61. It sounds like the answer is no.

(*Professor Kalmus*) We have a very similar situation. Because of the financial stringencies over many years now I think our community has very much optimised its programme so that we have given up things that we believe we cannot do effectively. The only things we do are things we can do effectively and those are cut to the bone. I think the answer within our own subject is that there are known things that we do easily and things that it is more difficult to do. As far as balance is concerned, which was perhaps the intention of your question, the balance between particle physics and astronomy or space science, I would just like to say that both areas are under enormous financial stress, both particle physics and astronomy and space science, and both areas are internationally recognised. We are enormously good at them and effective. That makes it extremely difficult to say would it not be better to move money from one area that is grossly underfunded into another area that is grossly underfunded? The analogy you might make is if you have a person who has not got one arm and a person who has not got one leg and you say should we cut off another arm or another leg? Both are very painful and it is difficult to know which patient may survive.

Mr Miller

62. If we are internationally respected, whether we go in or not go in to a new expensive project is not going to alter the fact that we are internationally respected. Expenditure on the LHC has meant that other projects, work on machines like LEAR, come to an end. What is the urgency in constructing the LHC? Professor Kalmus, you said earlier on it was the probable place for breakthroughs and Professor Rees said it was either the choice of staying or not staying in particle physics. What is the urgency? Would it not have been better to have delayed entry until existing programmes were themselves executed?

(*Professor Kalmus*) What you say about LEAR is sort of true but not totally. The LEAR Programme scientifically is winding down. In science programmes, as I am sure in many other activities in human life, it is very difficult to say "This is an end and you cannot do any more", but you get to a point of diminishing return. There is still some science that you can do but it is not at the same sort of level. I do not know of any facility that has been closed down in particle physics that is really still world leading, where one has not closed it down because there was no money but one has closed it down in order to put money elsewhere. Many facilities have been closed down—the ISR, LEAR is being closed down, large bubble chambers at CERN—they were all closed down at a time when the programme was not quite at the end but one could see already that it was providing diminishing scientific return. That is the situation with LEAR. We are now coming back to the timescale. If you look at the particle physics programme worldwide then you will find that there are results coming from facilities over the next five, six, seven years but not beyond that. If LHC does not come on in 2005/2005 there will be a fairly long gap between that start-up and any other scientific activity. It would be difficult for training graduate students, people would just leave the subject. To a certain extent it is continuity and the need in such large projects to actually have them go along. I should like to finally say that a project like LHC is a 25 year project. This gets to the point where people only work on one of these things in their scientific lifetime. If you make that 30 or 40 years then it will be like building a cathedral where you have to do it for your children and your grandchildren and I think that will not be very popular. I do not think it is possible. There is a natural order. I did a quick calculation once and I believe the five per cent reduction in the CERN subscription will lead to a three year delay in LHC. It will cost more if it takes longer, that is inevitable. The per year cost will be less but it will take longer.

Sir Trevor Skeet

63. Can I just ask you one question. Did we not unanimously agree in 1994 to go ahead with the LHC?

(*Professor Kalmus*) Yes.

64. Therefore, we cannot renege a year or two later on a negotiation which has been concluded?

(*Professor Kalmus*) I believe that to be true. What I do not know, and I am afraid you should ask Professor Pounds or somebody who would know much better than I, whether we also agreed to the funding level for the next ten years.

Dr Bray

65. If we are now committed to LHC, and you have made a very strong case for adequate levels of exploitation expenditure, however it is inherently a long-term field that we are in, may I ask Sir Martin Rees if the life of a project is 25 years how soon do you need to set the expectations of graduate students who are choosing their research path for the whole of their careers in order to anticipate something which is 25 years down the line in terms of the fulfilment of their hopes? Would it not be a sound judgment now to say: "LHC, fine, we will fully back it but we do not anticipate being able to advance money for a further machine at the end of that time"?

(*Professor Sir Martin Rees*) I can see, Dr Bray, the motive for doing that is a very good one which is to avoid raising extra expectations. I would only be slightly concerned that it might be very hard to make a decision now that would depend on scientific developments over such a long timespan, it is hard to predict such developments over much shorter timespans. Also, if this was an official or governmental decision then how binding would it be perceived to be if its effect was 25 years in the future? How effective such a declaration would now be I do not know. I certainly think it is terribly important not

[Dr Bray *Cont*]

to be trapped into a situation where there is expectation that everything is going to go on forever as it is now.

66. The substance of this Committee lies basically in the attitude of the scientific community.

(*Professor Sir Martin Rees*) Yes.

67. And if the scientific community says "So far so good but no further", and that is the judgment of the scientific community as a whole, that is a much more substantial judgment than that of this Committee or any Research Council?

(*Professor Sir Martin Rees*) Yes.

Chairman: Could I now turn to universities. Sir Gerard Vaughan.

Sir Gerard Vaughan

68. Let me change the subject. How dependent are you on the innovation, technological innovation, in the universities? What is your relationship with them? Is the funding adequate to support you?

(*Professor Sir Martin Rees*) You are referring to the support from PPARC?

69. Your disciplines requiring the technological innovation to keep up your supply, to maintain you.

(*Professor Sir Martin Rees*) This requires a level of funding on the grant side from Research Councils plus also, of course, the HEFCE funding for the well-found laboratory. Of course, as you will be aware this is something very much in jeopardy at the moment and this is a concern which we all have but which, of course, is far more widespread.

70. Now is the moment for you to comment on this.

(*Professor Sir Martin Rees*) Indeed, yes.

(*Professor Culhane*) Indeed, the PPARC subjects, in particular astronomy but I believe the others also, have seen in the past five years or so substantial growth in the number of faculty appointed within universities. I think that is a common experience in many of the United Kingdom's universities. These staff are now in post, they are gifted and in many cases prepared to carry on with the research. They do indeed need to be able to continue and for the universities, having backed the subjects through hiring and backing these people, it would be tragic if for whatever reason these staff cannot now be maintained in post. The underpinning of the research enterprise funded by the Research Councils is potentially in danger of being pulled out if crises beset universities forcing them to cut back and in extremis to lose staff. I think facing the serious cuts recently announced in the capital fund and, to a lesser but important extent, to the running budgets has the potential to do enormous damage. Certainly my university is very concerned about this and I have no doubt the others are as well.

(*Professor Kalmus*) I will try and answer the question that I think I understood you to ask. My subject is one that, as you know, tends to be very big science, very expensive and so on. It depends crucially on new instrumentation, new discoveries are made when you get new instruments, both accelerators and detectors. The interesting thing about this is that in principle it can usually be done on a fairly small scale, it does not require a large scale, and is very typical of the kind of work that goes on in university departments rather than large laboratories at CERN or my own laboratory, the Rutherford Lab. We certainly work with the universities, often on ideas that they have, but these are things which are very much university based. It can be done in universities on a small scale to demonstrate the principles. I think without it the subject just would not be where it is.

71. Are you warning us then that there are major problems building up over this?

(*Professor Kalmus*) Not really. Again, as is usual, we would like to put more funding through grants into this area. It is an area that does not require huge amounts of funding, it requires good ideas.

72. If I may just comment on this. I was told earlier today that one of the Research Councils are having more alpha level requests for funds than they can cope with.

(*Professor Kalmus*) That is true for us too.

73. And this is very serious for them.

(*Professor Kalmus*) I think that is true for us but given our general climate of under-funding this is yet another area of under-funding.

(*Professor Sir Martin Rees*) I just want to say that most of us who work on PPARC are in university physics departments and about 35 or more physics departments have an interest in this area and we would see ourselves as being concerned with the health of physics generally. It is certainly true that physics in universities is having problems which are aggravated by these recent cuts in the Capital Fund.

Mrs Campbell

74. I wonder if you feel that the UK is really getting its fair share from CERN in terms of intellectual development, industrial returns? What would happen if we decreased our subscription to CERN, would we see our returns decrease at the same time? Is that too much of a hypothetical question?

(*Professor Kalmus*) We may be able to get a decrease in our subscription on a temporary basis, certainly the Germans have done this, the Spanish have done it and the Greeks do it almost continuously. That may be possible for special circumstances. It is an international agreement which is based on national income. Certainly PPARC has not got the power to do that.

75. The question was are we getting our fair share back?

(*Professor Kalmus*) Let me tell you, yes, I believe we are getting our fair share in that if you look at various indicators like membership of committees at CERN, positions of responsibility, we do far better than our present proportion of commitment. Yes, we do. The point I would like to make is that I believe we are living off the past. Somebody said will we continue to be highly sought after? We paid our fair share ten or 15 years ago, we are no longer doing it. I believe we cannot go on and keep that influence if we just go on and on doing it.

Sir Trevor Skeet

76. But, Professor, talking about increasing subscriptions, is there not another way round this? The Japanese are using the facility, are they paying adequately? The Americans have closed down their facility, are they not contributing or are they not being sought after to become a member?

(*Professor Kalmus*) The answer is that they are both being sought after. The Japanese have actually put $50 million I believe into CERN. Negotiations are continuing with the United States and were disrupted, I believe, firstly by the great storm on the East Coast in the new year and secondly by the fact that the American Government closed down just at the time when Llewelyn Smith was over there to negotiate.

Mr Miller

77. Moving on to ESA, what would you do with it? Do you think it should be reformed and if so, how? Would reforms mean that science missions would mean a significantly reduced budget? Has ESA made the best of the opportunities offered by the satellites that have been launched?

(*Professor Culhane*) If I may take the last one first. I believe ESA has made excellent opportunities. I come back to my comment earlier though that the science programme, the mandatory science programme, and its staff and its operation in ESA is excellent. It is in part excellent, of course, because scientists from Member States drive the programme and dictate its composition but the execution of the programme, the design, the construction, the purchasing of the satellites and the building of them, practices which ESA deploys here I believe, could most certainly be improved. I think there is a philosophical issue. ESA is formed as an amalgamation of the old ESRO, the old purely science organisation, and the launching organisation, ELDO. I think at the time of that formation ESA felt it had a mission to develop and enhance the practice of all kinds of space activity in Europe, so in a sense it was protective, it nurtured, and it did not emphasise competition. I think the lesson now is that in the larger scale, in the industrial scale, frankly Europe is not competitive in the world space scene. Were ESA to take a more competitive attitude—I speak ideally, I am sure one cannot move immediately to any of these things—and, for example, to abandon the so-called *juste-retour* principle and have open competition, to procure assistance in a different way, place their contracts more competitively, all of these things would undoubtedly reduce the unit cost of a particular space science mission. I think the quality of the science is excellent and I do not see that declining. I believe the people in charge of that are from among the scientists of Europe themselves, Professor Bonnet is one such, I believe they do an excellent job. They are embedded in something much larger, the culture of which does need changing.

78. Is some of the pure science at risk because of the pressure to look at the commercial applications?

(*Professor Culhane*) No, the pure science is only at risk in as much as the cost of it is higher than it needs to be so the number of scientific mission opportunities per time is less than it could reasonably be. In that sense there is a risk but not, I believe, in the quality of the science.

Chairman

79. Could I ask you a question which I pick up from one which we might have caught on CERN. Both these organisations have substantial international collaborations, both treaty obligations, one with Europe plus Canada and Australia, the other with ten nations including the possibility of Japan. It has run through the evidence to this Committee this afternoon that the reduction of budgets, meaning a reduction at least in committed amounts so far as it observed the British as collaborators in these two international schemes, are having reduced budget problems. How does that affect, in your view, our relations with our international colleagues and compatriots on these two projects? We might ask Professor Kalmus first in relation to CERN whether he feels that our problems have seriously affected our relationships within the other countries internationally?

(*Professor Kalmus*) I think it would be fair to say that so far no. We are getting the reputation of being somewhat difficult to collaborate with.

80. That was always the case.

(*Professor Kalmus*) Yes, that is part of being invidious Albion or something.

81. Yes.

(*Professor Kalmus*) I do not believe that so far it has had a large effect although there have been actually occasions, and one example is you may know that we have a programme in Hamburg at DESY as well as at CERN and for that we only paid about 60 per cent of a fair share for the detectors. We were accepted because of our excellent reputation. They felt that they needed the intellectual input. I interact frequently with that community, although my own experiment is not there, at the sort of director level and I can tell you that I do not think they would do it again.

(*Professor Culhane*) I think regrettably the answer is yes, there has been an impact with our European partners in the space area. I spoke of our inability to proceed with INTEGRAL, a mission where our scientists had led the way in promoting it and establishing it. I think our compelled removal from that has done damage. It, in principle, makes us appear less reliable partners. I might say in addition to ESA there was a recent case in which we were sought after as partners in a smaller Japanese mission and they sought after us explicitly because of our skills in x-ray charge coupling devices because of the work we had done previously and we were unable to follow up on that. I know from personal conversation and contact that that has had a negative effect on our standing in Japan. These things are noticed and they do have an impact.

Chairman: Thank you.

Sir Trevor Skeet

82. Are you satisfied with the arrangements that we have at the present moment on the managerial infrastructure of ESA?

(*Professor Culhane*) I would repeat, I think, my earlier points in terms of the science in the programme, the selection of the science, the management of the science. Yes, I think we are satisfied. In terms of the execution of the programme I believe ESA has a culture which is risk averse to a somewhat high degree. I believe it could take a somewhat more relaxed attitude to reliability. It could procure things in a rather more effective manner. It could remove some of its layers of management. I am not a professional in these things, no doubt I could be argued against, but yes I believe improvements can and should happen.

83. Have you got any recommendations as to how that can be brought about? There are an enormous number of projects in which we could participate. We cannot afford most of them. What are you suggesting?

(*Professor Culhane*) I believe that the change in ESA's manner of conducting business has to be engaged on a much larger scale than just the mandatory science programme. I think this country should in all its dealings with ESA, and I believe it is attempting to do this, seek ameliorations of *juste-retour*, better procurement procedures, and we should do so in a manner that convinces the other nations and the interested parties in the other nations that this is in their interests also. It is no good saying "We are broke", we have to look for efficiencies collectively.

(*Professor Sir Martin Rees*) Now we have a single minister in charge of all dimensions of ESA then one hopes the opportunity will be taken to look into some of these concerns.

Mr Thompson

84. Can I just ask you about observatories, Royal Observatories, and the restructuring going on under the aegis of PPARC, as I understand it. Can you say something about the importance of observatories providing an astronomical and technical focus for United Kingdom involvement in large international projects but also their importance in other ways as well? I think I have already raised this question before in relation to their importance to education, public understanding and so on. Observatories is the question.

(*Professor Sir Martin Rees*) Very briefly, of course, the observatories now consist of the island sites in Hawaii, the Canary Islands (La Palma), plus also home bases in Edinburgh and in Cambridge. They provide the infrastructure of support which is essential because the ground-based programme involves very large numbers of university groups, many of which are small. One of the strengths of these ground-based programmes is that it is possible for individual scientists from small departments to apply for his or her time and get a few nights on the telescope. It is not a big science in the sense you need to be part of a big team to use the facilities, but in order to provide that sort of access and allow that number of universities to participate then clearly there has to be the infrastructure which is what the observatories are there to supply. They are also involved in other tasks like instrumentation and of course, as you were referring, the Royal Observatories in this country are well-known flagships, as it were, which do have a role in public understanding.

Chairman: Thank you very much for that good and sharp answer.

Dr Jones

85. We have had evidence to suggest that the transition from SERC to PPARC has resulted in major changes in the style and policy of your organisation, in particular that extra power has been taken by the PPARC Executive and there is obviously a role for the Director General. Is this satisfactory? Has this been an improvement or should there be further changes? Does the Council have sufficient expertise in order to take the decisions it has vested in itself?

(*Professor Sir Martin Rees*) There are two issues which I am sure you have heard from others who have given evidence. One is the interface with OST where the concern I know has been expressed by Sir David Cooksey which many other people would also share. As regards the internal structure of PPARC, there have been some concerns (I saw them expressed in the evidence from the Royal Astronomical Society) about the issue of whether there is, as you say, enough expertise on the Council to interface between the Council and the Committees. I personally do feel, as a Council member, that those concerns are well based. My hope is that the Chief Executive of PPARC will see that after two years, which he will have had by 1 April this year, it may be time to see to what extent the structure needs to be modified in order to take account of those concerns.

86. Would you here, in your personal view, recommend any specific changes?

(*Professor Sir Martin Rees*) I support all those points made by the Royal Astronomical Society.

(*Professor Kalmus*) Can I say that I would like to see the Chairmen of the Subject Committees being members, which I believe is one of the recommendations. I think this puts expertise into the Committee. I believe that the objections to this in the past are not really well founded. I think that if decisions have to be made which inevitably mean that these two people who are the Chairmen of the Subject Committees have personal axes to grind then they should declare their interests and not vote. I think the expertise it gives the Committee is very important.

(*Professor Culhane*) Briefly, in relation to points I have made relating to the management of our involvement in ESA I believe a more consistent and a higher level of expertise is required. Again, I would go with Professor Rees, the Chief Executive is well aware of these difficulties, let us see how they continue.

Mr Miller

87. I was being shown on Monday of this week the work being undertaken at Liverpool by Professor Gabathuler and his colleagues and particularly it related to some of your earlier comments about Atlas. Some of the interesting spin-offs from the work they are doing on detectors had an impact on other areas of science. One of Professor Gabathuler's colleagues put to me a point he held very dearly and that was that there are insufficient mechanisms for dealing with issues that are on the boundaries of one Research Council and another. The obvious example in his area of biophysics was the work that was being done on x-ray detection and possible medical applications of it. How would you see that being addressed in a visionary, revised Research Council structure?

(*Professor Culhane*) I think precisely this point was forcibly mentioned in the David Phillips' so-called Boundary Commission Report. I think the interfaces between these disciplines are absolutely crucial because by definition many of the next breakthroughs will occur at interfaces between existing bureaucratic structures. I think, however, that PPARC in many areas does seem well aware of this and in particular there are mechanisms in place to interact effectively with industry and I think that is going forward well. As to the interaction between the Councils themselves, I suspect there are possibilities for improvement there. I think one has to look at the original Phillips' advice and seek to implement it.

(*Professor Kalmus*) One thing that has got much better is the interface between particle physics and astronomy which is within PPARC which nevertheless was not very good under SERC and is much better now.

88. Does that not underline the issue that perhaps there could be better mechanisms, say, in this case for liaison between PPARC and the previous SERC?

(*Professor Kalmus*) We make strenuous efforts.

Dr Williams

89. If we look at the career paths of PhD students in the PPARC envelope—PhDs are expensive per capita as it were—only a quarter of them actually go into industry, the majority carry on in universities as lecturers or within the PPARC establishments. Is there not something inward looking and self-perpetuating about the kind of people that you produce? Does that give a distorting effect on British physics as opposed to Germany, Japan and so on who look more to applied disciplines?

(*Professor Sir Martin Rees*) I am not sure exactly what figures you are quoting but I would just like to say two things. First, that PPARC is planning to increase its numbers of research studentships by 50 per cent over the next two years but, of course, let us bear in mind that these numbers are still very small compared to the number of research students supported by EPSRC. It is our obligation to ensure that these research students do get broad training so that they are employable and, one hopes, desirable to a wide range of future employers. It is a role we can contribute to, that of education and training. Second I feel that the main role which our area has in education and training is at the lower levels as a tremendously valuable "heaven" to physics departments in universities and also at the school age level where the fact that the UK is known to be active in these subjects which attract great public interest may do its bit to stop too many of our brightest young people being turned off science irreversibly at the age of 16. If we can shift people towards some science at 16 that, I think, is an important role.

90. Could I just come back to that very briefly. If you compare us with Japan I am sure that our physics courses, or the way that physics is taught at 16-19, must be different. Their bias is very much into applied science whereas earlier on you were talking very much about basic science. Is that not a problem for us?

(*Professor Culhane*) If I can speak briefly for the space side. I think the implementation of instruments for flight demands very practical skills, not just in the development of the instruments themselves but in the management of the programmes. I know in my own department we are much sought after as teachers of project management courses to engineering and other departments. The skills required to produce space hardware, we certainly value them and we distribute them throughout the university.

(*Professor Kalmus*) One can look at the figures in the following way: 35 per cent of these students go into industry and commerce. There is essentially zero unemployed. They are highly sought after. Sir Martin has already said that we have a very low ratio of students per supervisor, this is going to go up and that means the number that go into industry will go up because academia is saturated. We believe the students are excellent, they will be highly sought after. If twice as many go into industry there will be no difficulty, they will be highly sought after again. We do get in particle physics and astronomy—there have been studies—the brightest students, the students with First Class Honours Degrees, they do tend to want to come into our subject areas.

Chairman: What a good point on which to end, best First Class Honours Degree students. Professor Kalmus, Professor Culhane, thank you very much indeed. Sir Martin, as ever, your Excellency, the Astronomer Royal, we are most grateful to you. Thank you very much indeed for helping with our questions.

Letter to the Clerk of the Committee from Professor J L Culhane (23.3.96)

I write in reply to the three points in your letter of 26th February on which you requested further information.

1. The mismatch between domestic and international spending is most acute in CERN, but the possibility of withdrawal from major facilities also exists in space science and astronomy. When should such decisions be taken and by whom?

I wrote previously that it is important for the UK as a civilised and developed nation to continue participation in the fundamental "big science" fields—Astonomy, Space and High Energy Physics. In continuing from that premise, I must address your question as a hypothetical one given that UK participation in astronomy and space science *does* require involvement in international collaborations. Thus without such collaboration, significant UK participation in these fields would be impossible. Were withdrawal from existing major facilities to be considered, the situation with ESA differs markedly from that prevailing in the ground-based astronomy programme.

The UK is a full member of ESA and therefore subscribes to the General and Mandatory Science programmes at a GNP-related level. The *scientific* basis for a decision to withdraw would need first to be formulated by the astronomy and space communities supported by PPARC. Such a course of action would require discussions with other key nations that possess launching capabilities[1] eg. USA, Japan. Starting from an agreed position of no confidence in ESA—which I emphasise does not exist at present, it would take no less than 2 years to establish the basis of a future programme with one or both of these nations. Assuming a successful outcome, PPARC—the Council, could then recommend withdrawal. The totality of the UK role in ESA would need to be considered in parallel so that Government would be in a position to decide on a complete UK withdrawal from the Agency. Notice of withdrawal would then be required with I believe a five year notice period. I emphasise that this would represent a total disaster for UK space science and astronomy. A coherent pressure to secure reforms by the major nations represents the best way forward through which an agreed restructuring of ESA with eg. the agreed abolition of the juste retour principle within the science programme, could take place.

For the ground-based astronomy programme, the situation is different in that the work is centered on individual facilities with finite lifetime and smaller scale than either the CERN machines or the space launching infrastructure. Here each facility is managed by a Director and run by an international board with membership from the partner nations. Individual nations can give notice of intent to withdraw with the notice period depending on the terms of the individual agreements. The ongoing basis for participation by PPARC in individual facilities is established by Council and is currently embodied in the Ground-based Strategic Review of January 1995. Council will continue to review the scientific return from each facility and presumably decide future policy on the basis of such reviews.

2. Does the UK have an adequate technical and managerial infrastructure to take full advantage of the opportunities offered by ESA?

At the scientific and technical level the UK has done well in ESA and was in fact the pioneer of space science in Europe. In spite of the damage done by our failure to participate in the INTEGRAL mission, I believe that sensible and firm polices executed with finesse will enable us to maintain our leading position in the Agency's programmes. There are at present several large UK University groups with established track records in the development, construction, management and flight of space instruments. These groups have tended to establish collaborative links with smaller groups and with scientists at DRAL to form winning consortia by making use of the best available techniques and skills. I believe that this mode of operation is highly cost-effective. Thus the kind of central management provided by DRAL for the High Energy Physics community to participate in the very large instrument programmes required at CERN is unnecessary in the Space field.

The UK subscribes approaching £40M/annum to the ESA Mandatory Science Programme and should spend about one third of this figure on the all important "domestic" programme which enables the exploitation of the subscription. I believe that the management structure for this activity, which is around 25 per cent by volume of the PPARC programme, could be strengthened. PPARC needs to devote more effort by experienced staff to the interface with ESA from within BNSC. Effort consistently applied within ESA in coordination with other aspects of UK space interest could in the short term better secure exploitation of our membership and in the medium term, generate an effective pressure for reform in concert with other member states. As a necessary corollary, provision of resource within PPARC for the ESA-related and the important bilateral space science programmes should be made more explicit than is at present the case.

3. Can the UK astronomy programme be operated without some central institution such as the Royal Observatories to provide an astronomical and technical focus for UK involvement in large international projects?

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[1] While Russia also possesses this capability, the country lacks at present the necessary stability to form dependable collaborations. However simple purchase of launch opportunities remains attractive particularly for small missions.

The Anglo-Australian Observatory has operated extremely successfully without the involvement of any such institution in either country. In this mode of operation, the telescope or site director has responsibility for the specification and procurement of new instruments. He exercises this responsibility with the approval of the relevant international telescope management board from within an agreed budget approved and established by the partner nations. Procurement from within the partner nations would be by open competition among Universities and other institutes with the necessary expertise. Within the UK, PPARC would be required to support an appropriate level of instrument expertise through small technology grants and contracts. For the comparatively rarely required major enhancements to telescopes or, even less frequently, the construction of new telescopes, the CLRC could provide engineering support for design studies and for the assessment of bids. For instrument design and production, the required level of engineering and project management expertise is well within the capacity of several UK University groups acting in appropriately formed consortia and involving industry where appropriate. Thus my view is that UK astronomy can operate without the existence of a central institution.

Memorandum submitted by Professor Sir Martin Rees (1.3.96)

The Royal Observatories are high-profile institutions with a long history, and PPARC is their current custodian. They have a continuing role as "home bases" for liaison with overseas sites, as centres for astronomical technology and instrumentation, and as foci for astronomical expertise and "public understanding" activities.

One of the strengths of the UK research community in ground-based astronomy is that it involves a very large number of universities. Small research groups can succeed because they have access to overseas telescopes, maintained and developed by the Observatories as common-user facilities. The staff in the Royal Observatories and at the overseas sites can provide the necessary support and expertise.

The interface between the "island sites" (Hawaii and La Palma) and the "home bases" (RGO and ROE) has gradually evolved. The Hawaii operation could in principle be made almost autonomous of any "home base" (though if such a trend is carried too far there's a risk that staff may "go native", feeling themselves part of the US community rather than our own). Such autonomy for La Palma (even if it were thought desirable) would be hard to achieve without heavy investment in a new sea level base on the island. For that reason, the close link between La Palma and the "home base" at the RGO is likely to remain necessary.

A committee which reported to PPARC last year concluded, after wide discussion with the astronomical community, that there was a continuing need for a central core of technical expertise in instrumentation technology. This has been traditionally provided by the staff of the Royal Observatories, and it would seem natural that this role should continue.

The Royal Observatories were for nearly 30 years run by SERC. During that time their role evolved as the overseas sites developed, and they contracted substantially. The "SERC establishment" mode of operation became unduly cumbersome for modest-sized organisations with a well-defined mission, and the senior staff were unduly burdened by micromanagement from Swindon. I hope we can move towards a modified system where PPARC and its officials have a more "hands off" role. Lessons can be learnt, for instance, from the system operating in the US, where such facilities are operated under contract by consortia of universities.

WEDNESDAY 27 MARCH 1996

Members present:

Mr Spencer Batiste	Dr Lynne Jones
Dr Jeremy Bray	Sir Trevor Skeet
Mr Ian Bruce	Mr Patrick Thompson
Mrs Anne Campbell	Dr Alan Williams

In the absence of the Chairman, Dr Jeremy Bray was called to the Chair

Examination of Witnesses

SIR JOHN KENDREW, SIR WILLIAM MITCHELL, PROFESSOR MIKE GUNN, Birmingham University, and PROFESSOR SIMON DONALDSON, University of Oxford, examined.

Dr Bray

91. Sir John, Sir William, Professor Gunn and Professor Donaldson, we welcome you. Thank you very much for coming to assist us in this inquiry, which we are doing into particle physics and astronomy in Research Councils. We have had evidence from the particle physicists working in the field. We thought it would be useful to have evidence also from scientists outside the immediate field who have had dealings with the subject and who are, therefore, able to comment on it a bit from our side, whilst knowing what they are talking about. Sir John, you chaired the Committee which looked at particles and reported in 1985, so we shall be very interested in how you see the scene, comparing it with the view you took at that time. May we, in that spirit, ask the very broad question, to which you might like to respond in turn: what do you think are currently the most exciting areas in science today?

(*Sir John Kendrew*) Of course, I would make a plug for my own subject which is molecular biology, but I would not like to discriminate really between it and astronomy and physics. They are all very exciting.

(*Sir William Mitchell*) I would say that the big scientific questions remain exciting: the origin of matter and the origin of life; but running through these things there is the whole problem, which occurs all over the place, of dealing with complexity. The things that PPARC deals with relate very much to the first of these origins, of the universe and, in particle physics, to the origin of matter and the ability to recreate conditions of the past when matter evolves through different stages. Although I am a solid state physicist and am outside the field, I find this of tremendous importance and excitement.

(*Professor Donaldson*) I am a mathematician and have less contact with the breadth of science than other cases, but for me and for many mathematicians the most important issue, at the moment, is understanding quantum field theory. This is the theoretical basis, which does not really exist in a form, at the moment, for the foundations of physics.

92. I am sure we will return to that. Professor Gunn?

(*Professor Gunn*) I would like to echo largely what Sir William said. It is very hard to give you a uniquely exciting area. Things can be exciting which are very complex, like biological and certain condensed matter systems on the one hand; or, on the other hand, they can be very deep philosophical questions, like the origin of the universe and what the beginning of time was like. This is partly addressed by astrophysics and particle physics, but it is terribly hard to order these different things and say, "one, two, three, four."

Sir Trevor Skeet

93. Would it not be true to say that particle physics is the basis of most modern technologies? Have they not grown through this in some way?

(*Sir John Kendrew*) I think some modern technologies come directly from it, but others indirectly only. Certainly there is a strong connection, but I would not say they all come from astro-physics by any means.

94. As far as the public is concerned, they cannot see any connection between mass and utility. Over the past 20 or 30 years a great number of developments have, in fact, come through this particular field. Would you itemise one or two things like imaging, for example, in medicine, or the Web?

(*Sir John Kendrew*) You are asking about technologies which have been—

95. Technologies which have come up, so as to familiarise the public with what achievements have been accruing in that particular field.

(*Sir John Kendrew*) Well, of course, one interesting small piece of technology, which has emerged directly from CERN recently, is the so- called World-wide Web.

96. That is right.

(*Sir John Kendrew*) I remember in the 1980s, when we did our report, the trouble was to find anything which had come directly from CERN. There was a lot of talk about spin-off and, of course, there is a lot of spin-off, but I think the first time something is directly coming from CERN is the World-wide Web. I do not know how many millions of people are using it. I am not yet but I plan to soon.

(*Sir William Mitchell*) If I could also add to that. I think the things that come from (let us loosely say) particle physics and relate to technologies come always with a time-lag; so the things which are, as it

[**Sir Trevor Skeet** *Cont*]

were, influencing technology—actually the World-wide Web is an exception to that—come from, perhaps, some of the things which particle physics was doing 20 years ago, and also come via the developments in condensed matter and so on. But on this specific example which you put, the Nobel Prize that Charpack won two years ago, this is a very special form of detector for detecting particles, and certainly has potential for real use in sensitive medical imaging. He set up a company (I am not sure how well it is doing) to do that. The sensitivity which is needed for the particle physics experiments means that those medical things, if it is carried through, will be capable of being done at lower dosages than taken previously. I think there is a connection. I believe these things can be followed through but I do not think—and perhaps this is what you may be leading on to—one can or should justify the doing and the cost of particle physics by these spin-offs which accrue. One has got to say that one does particle physics because it is an important scientific matter; but, by the way, things do spin-off, and the record of spin-off, either direct or indirect, is very clear.

Dr Bray

97. You are agreeing with the remark made in the Kendrew Report that: "any major technology base activity will provide spin-off, but there is a tendency to over-estimate the value of spin-off."

(*Sir William Mitchell*) That is what I am saying.

Sir Trevor Skeet

98. But there is a danger in this, is there not, Sir William, that if you say you cannot consider spin-offs so much—it is just the basic requirement of mass and research for this—are you not in a great difficulty because the public will say, "Why not spend the money on bio-technology where the spin-offs are very, very considerable indeed, and why bother about telescopes and CERN?" which they themselves do not understand and cannot see the advantage of.

(*Sir William Mitchell*) The public is actually more turned on scientifically by telescopes and CERN than it is by technology, since you have raised this. I do not want to engage in that particular argument but since you have raised the point: in terms of particle physics, I was President of CERN for three years—I have no connection whatsoever now—but the occasion of the opening of the lab, there were more column inches in United Kingdom papers of that event than there were of science in the rest of the year because the popular papers and others produced special supplements for it. We know people are excited about astronomy. The lectures given by Frank Close at the Royal Institution on Particle Physics were (by whatever means is used to assess this) viewed by more than any other lecture in the series of Royal Institution lectures. So there is a great interest in these subjects, I think. However, I do believe in the importance of spin-off, but I do not want each step to be gauged by what the spin-off was last year, that sort of argument.

(*Sir John Kendrew*) If I could speak as a biologist for a moment. My own field of research was protein structure, and still the only technique useful for determining protein structures is X-ray crystallography. Now, the Charpack detector, which Bill Mitchell has mentioned, has been of enormous direct value to protein crystallographers, who are trying to look at more and more complex systems. Furthermore, there is another development, this time not from CERN. The analogous machine in Germany, DESY of Hamburg, was the first place where biologists used the synchrotron radiation from a high energy machine to do crystallography of these materials which give very weak diffraction patterns. This, of course, has become enormously important. The European synchrotron in Grenoble is, of course, the most powerful in the world, and is also of very direct value to molecular biology. If such machines had not existed, I would be surprised if there would be synchrotrons available now.

Dr Bray

99. Would it suit your views if I made another quotation from the Kendrew Report which took the view, taken by Fineman, that: "The fabric of science is a net and there is no one part of it which can claim to be the most fundamental study imaginable."

(*Sir William Mitchell*) There are certainly a number of inter-connecting fundamental things. I would say there are others which are less significant. One of the things that I certainly believe strongly is the unity of physics, and the fact that there are fundamental aspects of particle physics—and solid state and so on—which have certain things in common. One of these is the business of phase changes which occur in very common matter—change of the structure of brass under certain conditions, the occurence of super-conductivity and many others—but the issue of the separation of the forces through the various stages follow the same general law. So, if you like, that is a connection and hence part of a network which is important. However, although there are connections, that is true, I would not necessarily tie everything into the same level of fundamentalness.

(*Professor Gunn*) Maybe I could add a little bit to that. Although one can certainly say, when you look at particle physics, that you are looking at more and more fundamental levels of science—and that is one of the things which makes it such a fascinating area—this does not mean to say that you can then derive everything, which is less fundamental, easily from the results you get from particle physics. So there can be a different branch which leads to biology, which is complexity, bringing many, many things together. The fact that you understand how each atom works does not necessarily help you to understand how the aggregate works. Therefore, there are different branches of fundamental nature. One is going to smaller and smaller things. Another is understanding what generic features can come from something which is intrinsically rather complicated.

100. So there are elements of complexity which just cannot manifest themselves at a lower level?

[Dr Bray *Cont*]

(*Professor Gunn*) That seems to be true in general, although not always. There are some phenomena which you could say are complex, but usually one is trying to isolate the simple things and understand them. It is really more Professor Donaldson's area than mine once it gets to that stage.

(*Professor Donaldson*) I do not think I have very much to add. It is certainly true that in science you study things at a different scale. You do not need—in fact, it is impossible—to derive things from a smaller scale, because the biological structures arise in different scales.

Mrs Campbell

101. It has been said that certain areas of basic science are more important than others. I wondered if you agreed with that. If so, where would you rank astronomy, space science and particle physics?

(*Sir John Kendrew*) I think I mentioned three areas. I do not think I mentioned space science but I did mention astronomy.

102. With respect, you were talking about the most exciting areas. Are those the same as the most important?

(*Sir John Kendrew*) Are they the same? Of course, this is a very deep philosophical question but I would say, by and large, yes.

(*Professor Gunn*) May I say something about this. I think there is actually a role for the less glamorous areas of astro-physics. One might say that understanding how stars work in detail is rather less exciting than understanding cosmology. The trouble is, in fact, that these things are inextricably linked. For instance, understanding how stars work helps you construct cosmological distance scales. If you understand how far away things are, really it is only once you have established that, that you can sensibly look at things which are much further away like clusters of galaxies, which tell you something more of the cosmological scale. So it is rather hard to untie this inextricable fabric of astro-physics, into the worthy bits which may seem less exciting, from the grand questions like ones of cosmology.

103. Would you place that at the top of your list as the most important area of basic science?

(*Professor Gunn*) Which one?

104. How stars work.

(*Professor Gunn*) No, I would not. What I was trying to say really is that it is rather hard to say, "Let us prioritise things and cut a few off the bottom," because then you find you have cut holes everywhere, that is what I was saying.

(*Sir William Mitchell*) Let me try to accept this challenge. The things that you mention certainly come in my statement earlier about the importance of the origin of matter, the origin of the universe and so on. I have been, in my job as Chairman, responsible for astronomy, responsible for space science, responsible for particle physics, and responsible for everything else, but as a solid state physicist and outside this, I think I would place particle physics out of the three you mentioned as ahead in importance. This arises because astronomy and space science are purely observational subjects. You do not actually derive any of the fundamental laws.

Dr Bray

105. Observational as distinct from experimental?

(*Sir William Mitchell*) That is correct.

106. No distinction from the theoretical?

(*Sir William Mitchell*) I am sorry, Chairman, as opposed to experimental; each of them, of course, has theory. But you do not actually derive—I am sure there will be some exceptions to this—the fundamental laws about the interaction of particles from astronomy or planetary science. The whole business of the internal things of stars came from the part of physics, nuclear physics of its day, in terms of fission/fusion, energy and so on. So I believe there is an edge which particle physics has there in that it does provide these laws. Of course, astro-physics does this very specifically and intermediately, in using those things and then in trying to understand the things of astronomy. I would not want to argue that terribly strongly but I do believe this is a real point.

Mr Thompson

107. May I come in on that point. I understand what you are saying and do not disagree with it, except to say that when we come to observational astronomy, because it is observational astronomy which led to Newton's laws on gravitation, *etcetera*—and you cannot get much more fundamental than that, and then you can follow that with Einstein and so on—I wonder whether your thoughts might be qualified a bit more than you did qualify them.

(*Sir William Mitchell*) I obviously accept that qualification. On the other hand, if you pursue the subject you have mentioned, Einstein's work related to experimental tests on a wide front including accelerators which would not otherwise operate, but yes, I accept the Newton point, using Kepler's observations.

Mr Bruce

108. Could I take a plebian view of all this and challenge you on behalf of, let us say, the taxpayer. It is always interesting to talk about Newton's physics, where apples fell down long before he theorised why they did so. But politics is all about making choices. You have all told us how exciting you find these fields, but how important is it to the United Kingdom scientific community and UK Limited to have a high standing within the fields that PPARC are funding, because one might argue that they will get done by other people with other taxpayers' money if we were not to take quite such a leading role. Is there, in fact, a cost to other branches of science—perhaps the rather-nearer-the-marketplace branches of science—by actually spending as much as we do on the PPARC areas? Indeed, does it matter that we are spending the money in PPARC rather than on those other scientific areas?

(*Sir William Mitchell*) Obviously money spent in one field cannot be spent in another. I also respond to you as a taxpayer. For a country, such as the United Kingdom, I would hope that it would be within our compass to be able to have some activity in some of

[**Mr Bruce** *Cont*]

these more important intellectual things—in the best sense I mean. Why should we, as scientists, be different in the desire to do that, from (let us say) other countries in Europe? I think the argument that one does not have to do it because it will be done elsewhere, obviously that is theoretically possible but it does not encourage the process of inquiry or the morale of people. It is also true that it is not the case that PPARC in the United Kingdom does all the subjects. It has opted out of quite a lot by this process of choice that you mentioned. That has happened certainly. I started doing research in 1946 and things in the 1950s were quite different. Things have changed and things have been dropped because we cannot do everything. I agree that we cannot and should not do everything; but basically the scientists have got to come to some understanding with politicians and Parliament that there are at least a number of things which they should be doing.

Mr Batiste

109. May I follow that on. Accepting the integration of scientific knowledge and research, and accepting the inter-connectivity which you have referred to, we are faced obviously with finite resources available for research; and the question which has been put to us on a number of occasions is whether, if there are limited resources, one is better to finance some areas well at the expense of under-funding in other areas, or whether to spread one's butter relatively thinly over everything. What would be your views on that?

(*Sir William Mitchell*) As a general statement, one has to fund certain things adequately. The United Kingdom has been doing that and trying to concentrate on the best ideas which come forward in different bits of science. In response to a general statement, I think that one has not got simply to divide the money by the number of people and spread it out. Having said that, the process of making those choices, of course, is that they are very, very difficult but they have been made, and there are some things which we do not do as a matter of decision. People could go abroad and find things. I was going to add a point which does relate to this because I think that the present set-up is actually discouraging those questions being addressed by scientists. There was a time when—I do not wish to argue on anything about the Science and Engineering Research Council—but the consequences of the broader Council, the members of the Council then, had to make decisions in which biology was put against particle physics and astronomy because they were all in the one Council; indeed, engineering too. In splitting the Councils up, the things that the PPARC Council has to do are much more limited; so they never have to think about biology or chemistry, and therefore they do a particular job. Of course it was said in the White Paper that there would be a council advising the Minister concerned in the OST and that scientists would be involved. They would be involved in making those choices and giving their advice and facing the issues. In the new system, since that council was never established, scientists are not having to think in those terms, whereas previously they did.

Dr Bray

110. We shall come on to that in due course. Professor Gunn, did you want to make a point?

(*Professor Gunn*) Could I come back to the question Mr Bruce was asking: why should we do it in the United Kingdom?

Mr Bruce

111. I was setting you a hurdle, saying, "Convince me why we should be spending the money in the United Kingdom."

(*Professor Gunn*) Perhaps I could address this, which may come up later on, and this is the recruitment of young people into scientific careers. It is important that when they see *Horizon* programmes on BBC2, which are sometimes about particle physics or astronomy, and which are one of the main vehicles which attract young people into science, that they see people with English accents rather than North American accents on those programmes.

Dr Bray

112. That sounds rather chauvinist.

(*Professor Gunn*) I am just being practical.

Dr Jones

113. The bottom line is here, do you think that PPARC subjects are given the appropriate level of support, particularly in view of the fact that we are committed, in the foreseeable future, to look at the subscriptions at CERN and so on?

(*Sir William Mitchell*) I think that given the memberships of those bodies, PPARC's budget is a little bit tight. I would not necessarily go along with what they say, but I do think they have some difficulties, yes. I have no connection with PPARC whatsoever.

114. How do we compare with other countries who are also involved in the collaborative programmes? I have some figures here which seem to indicate that we spend far less than France, Italy or Germany in relation to the experiments that we are able to do on this big machinery.

(*Sir William Mitchell*) I do not have the figures but, of course, as you rightly say, the system is that what CERN provides is the central machine, and the infrastructure associated with that. It provides a certain amount of help for the large experiments which go on, but Member States have themselves to fund those. However, I believe it is the case that we put in a little less than others, yes.

115. Is this because other countries give this area a higher priority within a budget which is similar to ours, or is it because they have bigger overall budgets anyway? Are other countries regarding particle physics as more important than, say, biotechnology?

(*Sir William Mitchell*) The two countries you mentioned have bigger budgets and therefore find it slightly easier, but they certainly do give priority sufficient to put in more work towards the experiments than we do.

116. Have any other people a particular view?

[Dr Jones *Cont***]**

(*Sir John Kendrew*) There is a particular problem in CERN and that is the exchange rate between the pound and the Swiss franc, which has been going down and down. The interesting thing is that our contribution goes up because our national product, if that is the right phrase, increases, so that is a kind of double penalty, and really not saying anything about the priority we or the French and Germans give to this field. We have just got a double dose of bad luck because of these exchange problems. What we spend on CERN goes far less than for other people.

117. So you could argue that if your GDP goes up, it is likely that your exchange rate strengthens the pound. I am not sure that those factors are necessarily moving in the direction you suggest.

(*Sir William Mitchell*) It is always argued—it was argued at the time of your Committee, Sir John—that this was a self-balancing thing; but it never works like that because there are other kinds of arbitrary political factors which come into the exchange rate, particularly in relation to France and Germany, for example.

118. But, in a sense though, we are committed to this. We are paying these subscriptions. Obviously everybody wants to keep them as low as possible. The point is, are we making use and giving the right priority to PPARC subjects in order to get the use out of those subscriptions?

(*Sir John Kendrew*) If you take the whole packet of what is spent on particle physics, partly the CERN subscription and partly what is spent at home, and if the economic situation and the exchange rate are against us for the main subscription, it means that we have less to spend at home. This is becoming an increasing problem. Indeed, I was sent only yesterday a newsletter from PPARC which makes this point very strongly. It does not give figures but the trend is clear that to contain the whole thing within a fixed budget is causing increasing and major difficulties; to look after the people at home who need preparation to make adequate use of the international facility.

Sir Trevor Skeet

119. Sir John, may I put a point to you. It is not only the exchange rate which is the problem here. It is also the increase in the GDP of the United Kingdom which forces our contribution, but is it not significant that neither of these are anything to do with science? It is the administration of Government generally and the prime purpose of the expenditure of PPARC.

(*Sir John Kendrew*) I would not like to assign blame, but I think it is clear that the exchange rate and the Gross National Product are nothing to do with the activities of science. But it is outside the control of the scientists, that is certainly true.

Dr Bray

120. Could I remind Sir John, in the conclusion of the report which you published, where you said: "There should be a progressive reduction in the total United Kingdom expenditure on particle physics, which had been modest up to 1989/89, but which would then increase to at least a 25 per cent reduction by 1991." In fact, it increased up to 1987/88 and then it remained about stable and has done so ever since.

(*Sir John Kendrew*) Of course, since we wrote that report the situation has changed, because a completely new machine came over the horizon and was agreed by all the Member States. This has really altered the whole picture. I must confess I have not followed the figures in detail between 1985 and 1996.

Dr Jones

121. When we saw Sir John Cadogan he said this was a decision taken by Government and by politicians. Do you think that is right? That if the scientists actually had an input, that the decision to go ahead with the LHC would happen?

(*Sir William Mitchell*) The scientists did have an input.

(*Sir John Kendrew*) They were very keen it should happen and very relieved that it did.

122. So, in fact, although your report suggested a curtailing of the expenditure, now that it has not been curtailed because of the LHC project, you still think that the right decision is to go ahead?

(*Sir John Kendrew*) Yes.

123. So if you were writing your report today it would be different?

(*Sir John Kendrew*) I think certainly it would be different but I would not like to predict how it would be. Also, I have to remind people that I was not the only author of that report!

(*Sir William Mitchell*) There is an interesting point, Chairman, about the level of the CERN subscription as paid in pounds. If I could just set the scene on this. The CERN subscription which one has to pay is really made up of three elements or processes. One is the actual work programme and what that work programme costs. This is where the scientists and the members of the Council of CERN can have influence. That is where indeed, following your report, a squeeze was put on the staff and the numbers went down by 10 per cent. That is the place where one can have an effect. Then the two other things: one, as Sir John mentioned, namely the relative GDPs which translate those Swiss francs into pounds. We get the really (I find) incongruous situation where if the British GDP does better—and jolly good!—the CERN subscription then goes up; but if the agency responsible for paying the subscription, if that activity is not also related to the GDP, the domestic programme goes down. It does seem quite incongruous to me. I do not know what the answer is, but it is certainly something that needs constantly drawing attention to. On top of that, of course, comes the exchange rate. It is right—and one of the contributors to Sir John's report at the time actually made this argument, Dr Jones, that you have put—namely, that these two things should balance eventually, but they do not. However, the point I wanted to make was that if you take the CERN subscription—not the part of the national programme—in pounds, and take it as a percentage of the science vote, it has actually gone down. The figures I have only relate from 1984/85 onwards. It was 6.63 per cent in 1984/85 and went down to 4.95 in

[Dr Jones *Cont*]

1993/94; a slight difficulty depending how you count because of a transfer of money (DR) from the UFC, as some of you will know, came into the equation, but it does not make a great deal of difference to the figures I have quoted. So the CERN subscription as a proportion of the science vote has gone down certainly over 20 years.

Dr Williams

124. Relating to what Sir John Cadogan told us in evidence about one month or so ago, he is the Chief Scientist at OST and in the latter half of his evidence to us he was deeply sceptical of the value of particle physics or the CERN subscription, set alongside the total science budget. I will just give you a couple of quotations. He said that it is a Government decision so there is no choice between. "I have to say that everybody outside particle physics would say: 'Do not be involved at all.'" He goes on: "I have to say that when I conducted my review of this for the science base nobody except for particle physicists spoke up for it, nobody."

(*Sir William Mitchell*) I am glad you have brought that up. I was hoping to find an opportunity to do so. I am not going to mince words about this because I believe that is nonsense. Sir John is somebody I have known for a long time and in many ways he has a characteristic of firing from the hip. Some of his shots are absolutely right, such as it is a Government matter in the end, that is obviously correct, but I also have the quotation here. "I have to say that everybody ...", "everybody" is what he says. He might not have meant to say "everybody" but that is what he says, "... everybody outside particle physics would say, 'Do not be involved at all.'" Now, I am not going to speak for anybody but myself, but I for one am not included in that. Sir John makes this kind of statement from time to time to emphasise his point. I furthermore know industrialists who are not included in the follow-on of his remarks. "The industrialists just could not understand it. 'It is all a waste of money,' they said." Maybe Sir John might be asked what the basis of this thing about "everybody" actually is. It is not even the case that he can have said "everybody on my advisory committee" because he has not appointed an advisory committee, so he was speaking for himself.

Mr Thompson

125. So he was speaking for himself?

(*Sir William Mitchell*) But if he was speaking for himself he cannot say "everybody".

Mr Thompson: I am just helping you.

Dr Bray

126. Could you name the industrialist?

(*Sir William Mitchell*) I think that Sir Martin Wood would be one.

127. Who is a manufacturer of super-conducting magnets?

(*Sir William Mitchell*) Yes.

Dr Williams

128. Did Sir John wish to say anything?

(*Sir John Kendrew*) Only that Sir John Cadogan did not consult me. If he had consulted me then his generalisation would not have stood up because I would certainly not have said that it was a waste of money.

Dr Bray

129. Professor Gunn and Professor Donaldson, would you like to comment?

(*Professor Gunn*) I would also like to exclude myself from Sir John Cadogan's evidence. I think that most other physicists outside particle physics certainly see the value of it.

(*Professor Donaldson*) I agree. It seems a very surprising statement and does not agree with my own views, nor I think has it widespread support.

Dr Williams

130. What end do you think there will be within that science base, since the CERN subscription has been going up for reasons outside of our control? Will it squeeze the pressure right across the science base? People working in other fields on limited tight budgets are bound to ask: why is CERN such a sacred cow for the Government? Why is it such an albatross on the science base? Is it really that important? Why should CERN be so uniquely protected when because of the decline or differences in currencies it is really hitting other areas?

(*Sir William Mitchell*) I can only speak for myself as a solid state physicist in that. I would observe that, as I mentioned, the proportion of the science vote going to the CERN subscription has gone down despite all these statements. That is the first point. You have to think: how is one going to handle these large things? To start, there has got to be a scientific voice and scientific opinion and then this becomes a Government treaty. I think the issue with CERN is that from time to time there are major reviews. Sir John's was one. That major review did not say, "The science that CERN is doing is not done well," and so on. I think the answer that I am happy to accept is that this proportion is going down so it is, as we said earlier, obvious that if money goes there it cannot go elsewhere; but, nevertheless, there has been some headroom, some increase of funds, over this period of 20 years to other fields. Because of the importance of science and the excellence with which it is pursued—four Nobel prizes over the last ten years—I would accept that this is something which is worth doing, even though it might be squeezed.

131. Is there a better way of organising this CERN subscription? Spencer Batiste and I had a conversation about this, coming from Oxford last Wednesday, is there a better way that you have considered than being at the mercy of the international exchange rate?

(*Sir William Mitchell*) I think there was a definite improvement in the way that OST has handled this and, in this instance, I think Sir John Cadogan was right in top-slicing and not putting it all on the individual council, which was what happened in my

[**Dr Williams** *Cont*]

day. I know it is sometimes said—I actually do not believe this but it is sometimes said - "Oh well, some other aspect of Government should deal with it, the Foreign Office," and so on. I think we have been through all that before. The money is simply sliced away and taken away from one and put to another. This does not solve anything, although some countries do that. I think the top-slicing of the whole vote, if your review said that it is still good science and we must still be doing this, then it seems to me that for a number of years you have got to find the means of paying for it.

Mr Batiste

132. Could I come back to this point, because several people have put to us a proposition that in relation to CERN, and the cost of the subscription for being in as members, that this is having a very damaging effect on the ability of national projects to build up behind them and to do projects on CERN because there is not enough money available; and in the space programme there is an obvious cut-back on a number of things which we would have funded had it not been the cost of the subscription. At the same time, I was looking at the CVCP's offering on the EU Framework Programme V, which emphasises the need to maintain quality in the Framework Programmes. It seems to some people that a very sensible use of European Framework Programme money might be to pay the subscriptions to CERN and ESA of those Member States who belong to ESA and to CERN, to take a subscription and open the way to very high quality work in all the Member countries concerned; and it would be a more appropriate way of dealing with what is, after all, an international collaborative organisation. Have you any views on that?

(*Sir William Mitchell*) It is a very interesting proposal. There might be little problems about slightly different membership but this could be looked at internally. I am sure you are aware of this. I was going to add that there is a significant difference in the nature of the subscriptions to the two bodies ESA and CERN. 80 per cent of ESA's space agency's activities are optional programmes.

133. So in relation to ESA, this means that there is a compulsory science structure?

(*Sir William Mitchell*) I was coming to that. 80 per cent is in the loosely called "industrial programmes" or whatever. For a Member State to have the ability to take part in those, it has to contribute to the mandatory science programme; so the mandatory science programme is there as an entry which gives the possibility to do these other things. DTI has a vested interest in ESA, and a subscription to one of these things is to encourage the industrial activity. So there is a difference between the two on those grounds. It is a very interesting suggestion but I do not doubt that this having been said, that the amount might go up a little.

Dr Bray

134. But you are saying that this would be a European organisation?

(*Sir John Kendrew*) In fact, the European Molecular Biology Laboratory treaty was more-or-less a Chinese copy of the CERN Treaty, with very slight changes. We did have experience of countries in difficult economic situations wanting a reduced subscription—and that can happen and has happened both in the molecular biology lab and CERN—but the conditions for it are rather stringent and involve the country going through very serious economic difficulties. I think in the case of CERN, it happened when there was the reunification of the two Germanys because there was quite a financial problem there. In the case of the molecular biology lab. I remember it happening with Israel, which was a pretty small contributor anyway, and for a year or two our Council made it possible for that country to pay a reduced subscription.

135. Would it have worried you if the MBL subscription had been paid from the Framework programme?

(*Sir John Kendrew*) As a matter of fact, that laboratory is getting quite a bit of money from the Framework programme now. In the early days it got nothing from the European Union. As Bill Mitchell has said, the membership is not congruent and so there are some problems, but I think that this would be a very interesting idea indeed.

Mr Thompson

136. Moving away from CERN and perhaps coming back to enthusiasm for astronomy, after all, I think the public understanding of science is very important. Today it is fine and certainly when this is over we will all go rushing out to see if the comet is at last visible and there is great public interest in this. How important is it for the sciences supported by PPARC to be understood by the general public and how important are the disciplines funded by PPARC in fostering enthusiasm for science as a whole? I fear I have given my own prejudices away, but never mind, let us put the question.

(*Sir William Mitchell*) I think that it is very important for PPARC to convey to the general public what it is up to and I believe that is true of any science. I even think it is true of mathematics, but I think that any set of—let us call them academic people—pursuing whatever subject, if they get totally isolated and totally cut off from the sort of mainstream of cultural interest, that is a bad thing. That is not to say that you can convey in any kind of detail, in a way acceptable to the professionals, what these things are but you have to make the attempt, and I think the money that PPARC spends in doing that is very important both in astronomy, space and also in particle physics, and I would say any science, but in the end it comes back to what you were saying about carrying the taxpayer and so on.

(*Professor Gunn*) Could I add to that that I agree with everything that Sir William says but I would like to differentiate slightly between the appeals of astronomy and particle physics. I think astronomy probably appeals to a very broad range of people in

[**Mr Thompson** *Cont*]

general and particle physics perhaps a little bit less so. On the other hand, it is very accurately targeted because I often interview prospective undergraduates for our university and if you ask them what interested them in physics at the start you will find it is a fairly even balance between particle physics and astronomy, maybe even slightly more in terms of particle physics. So in that rather crucial area, which I agree is not perhaps spread over the whole public, particle physics as well as astronomy is rather an important ingredient.

137. Was that not supported by a recent survey done by PPARC itself? I know this is more to recruitment of young physicists but it is all tied up together?

(*Professor Gunn*) Yes.

Dr Bray

138. Could you answer a specific question on the question of mathematics, whether you think the fundamentals of particle physics really can be understand from anything but a mathematical point of view?

(*Professor Donaldson*) I think not properly but that is equally true of a great many things, even things such as quantum mechanics, how atoms behave and so on. Really it is true for pretty well all science, that you cannot understand those properly from that point of view, but there are still aspects that can be conveyed. I think that the notion of particles, quarks and things one can convey, at least part of the truth, without any mathematics.

139. The subject itself depends upon establishing the logic by which quarks are related to experimental evidence and so on and that is a highly mathematical process?

(*Professor Donaldson*) Yes.

140. Can it really be understood in a strictly mathematical way?

(*Professor Donaldson*) No, I do not believe it could, but perhaps we should say more that it is not understood with the mathematics, because mathematics one is trying to imbue known techniques to, and large parts of science are of that kind, but it is these other areas where one is searching for the right mathematical ideas to describe these things and there have been enormous advances in the last 50 years in that direction.

Mr Batiste

141. We have been told in the course of the inquiry so far that there are a lot of things in common between astronomy, space science and particle physics that make things stand apart from things and it is the continuity of the science that binds them all together. There is the very high cost of the international subscriptions, there is the fairly high level of international integration in terms of the international co-operation so far as the sciences are concerned. On the other hand, you told us this afternoon that, so far as making scientists make value judgments across the range of sciences that has had the effect of almost putting it into a little ghetto of its own and separating it away from common decision-making. Do you think it was the right idea to set these three sciences into PPARC away from the rest?

(*Sir William Mitchell*) I think you can make administrative structures which you can operate, so there is not a right or wrong answer to this. I think I saw the logic of doing it, which was a science logic, I think, and the other factors you mentioned, but the thing that has taken away the role of scientists making those kinds of severely cross-field comments, certainly it is true that PPARC has contributed to that by being small, but if you accepted that argument, where should this other discussion take place—biology, astronomy or whatever—and we all thought it was to be in the advisory committee that was advising the minister, the secretary of state, and it was in the White Paper as such, but it has never appeared. Sir John Cadogan says he asks his friends[1] about what they think but that is no substitute for scientists taking part, admittedly advisory. So I think that cross field comments are a smaller part of the system but not because of PPARC itself; but the people who were, as it were, constructing the system would answer you by saying this could be done at the advisory committee or council.

Mr Bruce

142. Perhaps the Committee has gone back to fundamental particle physics, that is, that the best committee is a committee of one!

(*Sir William Mitchell*) Yes. That, of course, is what used to be said of Cherwell in his day. That is fine in an ideal world but it depends a bit on the one.

Dr Jones

143. Was PPARC created because it had a different mission statement from the others? Is that right?

(*Sir William Mitchell*) No, I think it was created because, in my opinion, scientifically there is no doubt that over the last 20 years or so elements of particle physics, elements of cosmology, have come together and the sequence of early processes in the evolution of the universe are very much governed by things which the particle physics were determining. So there is a scientific attraction to saying these things relate and I think that was in people's minds at the time; I think also maybe the fact that they are all so international and big and maybe it is going to be easier to handle them that way. But I think there was a real kind of statement related to the knowledge.

Mrs Campbell

144. My question is specifically for Professor Gunn. How does your work relate to PPARC's work and have you experienced any difficulty with the Research Council re-organisation?

(*Professor Gunn*) Maybe I could separate those two questions a bit because partly I was thinking of a response to the previous question which relates to your second one. In terms of the first one, there

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[1] *Footnote by witness*: "an informal open circle"

[Mrs Campbell *Cont*]

certainly are relationships, albeit spread over quite a long timescale. There are examples both of work which started in particle physics and entered into theoretical condensed matter physics my work and also things which have gone in the other direction, for instance all this idea about phase transitions such as water boiling in the early universe affecting cosmology. A lot of that work came originally out of condensed matter physics and then translated into part of astrophysics. On the other hand, what appeared to be a very mundane thing, which is to understand how elastic bands work, some of the ideas which are used in that general area actually originated, rather surprisingly, in particle physics in the Fifties and in the Sixties. So there is a transport of ideas in both directions and I think that is a very healthy thing. I would have to say that really there have been no barriers placed to that transport by this separation of PPARC from my own area. Just to come back to your second question and also the previous one, I think actually the way some fundamental scientists within the EPSRC area view PPARC is as being a shining and wonderful example and they rather view it with envy when compared to their own Research Council, but I am sure you will be hearing more about that when you come to review EPSRC.

Sir Trevor Skeet

145. Sir William, perhaps I should start with you on this one. I have noticed that PPARC has decided to cap the expenditure. I approach it from this angle, that when the LHC budget was authorised, and it was authorised unanimously in 1995, there was going to be a three-year freeze of the budget anyhow and that would take it well beyond the current date, and also the expenditure thereafter was to be indexed at 1 per cent. per year. In view of that, was it right to cap? I also use a further argument, that you have had three general inquiries, quite apart from Sir John Kendrew, in 1985, 1987 and 1992. Have we not had a thorough review of this and are we not simply repeating the same exercise to put forward ideas which are not essentially sound?

(*Sir William Mitchell*) I am not fully conversant with what PPARC did last week but if the things that I have heard that it did are true, it is bizarre what they have done.

146. Yes, exactly.

(*Sir William Mitchell*) Going back to what was agreed in 1995 at CERN, that was, of course, an agreement in Swiss francs and everybody agreed that Swiss francs would be one of the figures that was to be frozen for three years and then 1¼ per cent.—I forget the figure—and, of course, PPARC's problem is back to the exchange rate, which is that translating even that agreement into pounds gives them a problem. But I do not know—and it is not for me to know—what exactly PPARC is playing at because it says, "Cap CERN," which requires the government to do something about the Treaty, and then it says, "If you succeed, by the way, give us the money," and it seems to me that that would be the last thing that would happen because if a thing which is the government's responsibility is by that kind of international action decreased, it would not automatically go to PPARC, it seems to me, so I do not know what PPARC was doing in that.

147. You can see the absurdity of that. I think everybody around this table can, too, but surely when one has an international rate of the LHC negotiated in 1995, which is a long-term commitment, how can PPARC possibly come forward with a proposition that they want a capping arrangement which would be binding on the government of the day virtually?

(*Sir William Mitchell*) I do not think they can but you must ask them about it.

148. Perhaps Sir John Kendrew has a view on this?

(*Sir John Kendrew*) I was surprised, too, and that is all I can say.

Dr Williams

149. This is to Sir John. I understand you carried out a review of CERN or particle physics in general back in 1985. If you were to carry out that kind of review now, what conclusions would you have that are different from what they were in 1985?

(*Sir John Kendrew*) Without actually doing it it is hard to say because the situation has changed. CERN has a completely new programme, which, by the way, was unanimously agreed to by all the Member States, and that is a fact and you cannot really do anything about that. Either you leave altogether, which can be done in 12 months' time by any member, or you have to go along with the Treaty and if you want changes you have to persuade the other Member States to follow you. That, of course, is a perfectly reasonable way of proceeding but it takes time, and I must say my guess is that if we were doing the same inquiry again we would probably say that there is really nothing to be done while the LHC construction is in progress. CERN, in fact, does have a good record of doing things on time and within budget. I wish other organisations had as good a record. They are pretty good in that respect and I think they are on course this time. But I do not think it is realistic to think that you can really change anything until that programme is complete, until the machine is working. What happens after that is another problem, of course, and that is very important for all the Member States to think about and I think our input is very important there.

150. Given this enormous time-lag between beginning to conceive of the LHC and its construction and then its full life, should we now be, or very soon be, thinking about what comes after the LHC and planning ten or fifteen years ahead and really envisaging very seriously whether we can afford whatever it is that comes after the LHC because it is likely to be two or three times as expensive again?

(*Sir John Kendrew*) I think we certainly should be thinking about the future. I have no doubt about that. Of course, the trouble is that the future of all science is unpredictable in detail. You cannot really see what is going to happen more than a year or two ahead. It is well-known, for example, that Rutherford said in the middle Thirties to a pressman that he could not see any practical value coming out

[Dr Williams *Cont*]

of nuclear physics, which was only about five years before the Bomb happened. He was completely wrong and that is the difficulty about prediction, particularly quantified predictions, but, of course, we should try and do it.

Dr Jones

151. Were you wrong then in saying in your report that particle physics expenditure would be reduced by 25 per cent. by 1991?

(*Sir John Kendrew*) I think it was a pious hope.

152. But the fact that it did not happen, the implication of all you have said this afternoon would be that you are not disappointed that it did not happen?

(*Sir John Kendrew*) I think they have a splendid plan. I think LHC is a wonderful machine. It is evidently going to work and do great things, so from that point of view I am delighted.

153. Do you think it was sensible to have your sort of review? Are these reviews of any value if they cannot actually look ahead and predict?

(*Sir John Kendrew*) I think some people thought that our review might come out with the conclusion that the United Kingdom should resign from CERN. We did not do that but I think that was in the minds of people.

154. So are you saying you were operating within a framework which expected you to say, "Pull out completely," and, therefore, "Reduce by 25 per cent." was actually being quite brave and supportive of the area?

(*Sir John Kendrew*) Some people, I think, hoped we would say we should leave CERN altogether. I think the membership of the committee was interesting. It included, for example, one very distinguish industrialist, Lord Francis Tombs, who was the Chairman of Rolls-Royce, and we also had an economist, Sir Douglas Hague. It was quite a varied group. It had no high energy physicists, although you may be interested to know that I asked at the beginning if we could have a consultant who was a high energy physicist to brief us on important scientific matters and they said yes, so I got them to agree to have a Fellow of my own college at Oxford. He is now the Director General of CERN.

Sir Trevor Skeet

155. Sir John, can I ask you two short questions. One is that there are a lot of non-member users, I think something of the order of 30 of them. Could they not be persuaded to subscribe additional funds? The USA I have in mind and, of course, I have the Japanese and others?

(*Sir John Kendrew*) I do not know anything except what is in the newspapers, but with those two countries there certainly are very active negotiations going on. One of the problems is—and I cannot remember, this was in the press, I am pretty certain—it was agreed by the Council of CERN that if new countries could be persuaded to contribute I think they could not be members of the official CERN because the Treaty says it is European countries, so the United States and Japan would have to have some other status, but that if they did contribute substantially this would not be used to reduce the subscriptions of the Member States but to improve and accelerate the programme. I believe this was decided. Again that was a decision of the Council of CERN. I do not know what the United Kingdom said about it.

Dr Bray

156. Can I ask Professor Donaldson and Professor Gunn a question. We have been told that there is a physical limit to the energy level up to which you can build a particle accelerator. Supposing there were no particle accelerator built after LHC for 50 years. Do you think in 50 years' time particle physicists would want to be building the next marginally bigger accelerator than they had before or would it be something totally different, given the developments that would have occurred in theoretical physics in the meantime?

(*Professor Gunn*) Maybe I could start off. I do not think so. There are developments on the horizon in accelerator technology that might very well make radical progress so that one should not perhaps extrapolate to say the next machine is unbelievably expensive. Certainly one of the things I know about personally, because it happened at a lab I worked at until a few years back, is a thing called laser beat wave acceleration. At the moment that is still very much in a development scale but there may be some hope that on the timescale of ten years or so, when we might be making a decision about the next accelerator, there could indeed be some progress in that area. So I have not quite answered your question but I have said that maybe the situation will have changed sufficiently by the time one has to make that decision, that maybe building another machine would be a more serious option than it looks at the moment.

(*Professor Donaldson*) I think it would depend whether you mean scientists in the world as a whole. There would be one case when it was only Europeans who had built a machine and another case when no-one built a machine. I think in the second case a lot of the excitement would go out of perhaps science as a whole, particularly if it was a case of very fundamental issues that would be resolved by being able to do some further experiments. I think there would be a lot of pressure to do this.

157. I am not asking you about the desirability or otherwise of not building a machine. I am asking you to speculate on whether, given 50 years' further thought—

(*Professor Donaldson*) There would be something different.

158.—in fact particle physicists or fundamental physicists or whatever kinds they were in 50 years' time, would have some totally different kinds of experiment they would like to do?

(*Professor Donaldson*) They have been doing them for 50 years.

[Dr Bray *Cont*]

159. It is only speculation, but Hewish, the radio astronomer, thought that the energy levels might go down indefinitely through successive layers. That seems to me to raise very fundamental questions indeed.

(*Professor Gunn*) It is very hard to know whether that is true or not. It is very hard to speculate.

160. But no experiments of our present kind?

(*Professor Gunn*) One could argue by analogy that every energy scale which has ever been explored has had phenomena within it, and so that would argue that until one ends up with planck length, which is the shortest length that one can really speak of, there should be phenomena to be seen, but obviously how intermittent those phenomena are in terms of orders of magnitude, that is the impossible thing to speculate upon. Could I also say that maybe the other thing that you are thinking about is that there are other ways of doing particle physics experiments. There are almost cubic miles of dry-cleaning fluid that have been used to look at proton decay and things like that and although those experiments are very valuable and dark matter search and things like that, in some sense they are a much cruder form than accelerator experiments where you can vary lots of parameters and really see what is going on. It seems hard to believe, at least at the moment, that they could take over.

(*Professor Donaldson*) On the whole they have failed.

(*Sir William Mitchell*) Could I answer further Dr Jones's question, if I may, because I think that reviews of the Kendrew type are extremely important because it ascertained at that moment that this was good science, that, however, there were things that could be done better in the way of use of staff and so on. What happened to that was that it was absolutely a key thing in setting up the international Abragam Committee, which in fact I went with the minister to the Council to do, and the Abragam Committee did essentially a Kendrew but for all countries and came up with very similar conclusions. I think that would not have been triggered without Sir John's report. So these things are important and certainly in the SERC after the time of Sir John's report the budget was increased in terms of the domestic programme for a number of years arising from that and the Abragam Report came out and it actually talked about a 10 per cent. decrease of staff, which was achieved, and so on, and it gave a statement about the subject at that point, which I think was very important. I believe certainly from time to time that has to be done. You do not want to be doing it all the time. But if I could take the time to comment on something else that came up about the LHC, because I think this is an interesting point which the Committee might like to note and it also relates to what might be happening in X years' time, the LHC is actually a very flexible instrument. Of course, it is in the same tunnel and it is going to do proton-proton collisions and it is also going to do so-called heavy ion collisions, which matches the interior of stars, which also relates to these two fields. It is possible that since there are electrons there and protons there it could actually do an improved version of what the German machine, DESY, does. So it has enormous flexibility, so that without actually a completely new structure you can see new things going on. What the scientific requirement will be within that spread is not clear at the moment, for reasons which Sir John has said, but you can see things happening. If I can make a comment which does relate to funding, we talk about CERN and how it should be made more efficient and the pressure must always be kept on for that, but there is also efficiency of capital utilisation as well as the operational side and CERN has actually done extremely well on that. It has used its past capital investments, and I noticed in some of the papers we were sent related to the SSC, the American machine and why was that stopped—in my belief it was stopped because it was an improvident machine. They did not use or utilise any of the previous investment as they could have done in going to the SSC and that is why it was costing $12 billion and why the CERN machine over a period in terms of new—not new money but from their running of the budget—is costing 2 billion over the ten or twelve years. So I think that CERN does utilise its capital and its past capital very effectively and the reason why the SSC did not go ahead was that they did not. One of the reasons was that it was just too expensive because of the lack of utilisation of past capital.

Sir Trevor Skeet

161. Can you explain one thing, Sir William? There were 19 contributors to the budget of CERN. That being so, it seems to me that we, the United Kingdom, are taking a rather negative attitude to it. What is the attitude of all the other countries? They appear to be going along with it and finding it very satisfactory?

(*Sir William Mitchell*) The GDP formula is a formula basically of equal pain. That is the theory, so that it should not be better or easier for one country or another country. There are some exceptions. Greece has never paid its full subscription; Spain had a crisis when it broke the law.

162. They left and came back again?

(*Sir William Mitchell*) They left and came back again and they even broke it again. I do not think our government would wish to do that but in the rest of the countries sometimes there are difficulties and arguments and so on but they manage.

Dr Jones

163. Do you think the reason CERN has been relatively cost-effective is because it is an international collaboration whereas in America it was just basically one country? Is it being more effective because it is international rather than, say, if we had the resources to do it in one country, if money was unlimited and we did it here?

(*Sir William Mitchell*) There is a competition involved in terms of the things that those different Member States actually produce and I think also there is pressure because it is dealt with in just about all the countries through the science vote essentially, whereas the American scheme was dealt with through the Department of Energy to which it had no natural affiliation.

Mr Batiste

164. It is probably the only international collaboration that has been more effective in terms of its administration costs than a strictly national programme?

(*Sir William Mitchell*) If you put the question that way, there is no doubt that it is very effective and efficient. To go back to your earlier point, the only hesitation I would have about your interesting suggestion about the EEC paying the subscription is that I sit on the ESTA, the thing that used to be CODEST, advising the Commission on science and technology, and I would worry about that administration dealing with the business of CERN, but presumably there must be some way around that. But there is in CERN a sort of will to try and come to conclusions and work and do things and there is a history of doing it, as we were saying, on time and to budget, instilled by John Adams, I guess, initially.

Dr Bray

165. With this flexibility, one recommendation made in the Kendrew report was the case that major capital expenditure at CERN should be reduced by extending the periods between upgrades or between new machines. If there is going to be a continuous process of upgrading, then that does allow you to vary the rate of capital spending. Do you think that you would still support that recommendation?

(*Sir John Kendrew*) I would still support that, yes, certainly.

(*Sir William Mitchell*) And CERN followed it on that. There was a saying around CERN and the Council that time was the contingency on that.

Mr Thompson

166. Just going back quickly to the supply of young scientists—and perhaps these questions are in the first instance for Professor Gunn and Professor Donaldson—we have already referred to the survey of new physics undergraduates. What would be the impact on student recruitment into the sciences if the resources going into PPARC science were increased or decreased? What is the relationship there? And can I couple that with the following question: how important is the teaching of PPARC science in the courses which are laid down by your department or university? I couple those two questions together because really they are related.

(*Professor Donaldson*) I personally see the people who will be very directly affected by this but, as I said before, if that kind of science was not done it would undercut the excitement from the whole swathe of science and so directly would have a very large effect.

(*Professor Gunn*) I think it would affect things very greatly. As I said, when I interview prospective students they always really say one of two things, either it is astrophysics or particle physics that got them interested in the first place, and although you could argue those subjects might occur somewhere else in the world, eventually the students would realise there would be no future for them to do such things, if they always hear foreign accents on television programmes, so I think it is terribly important. Once they are there at university, of course you can persuade them that there are other aspects of physics, other aspects of science, that are very interesting, but you get them in that way and then persuade them that other things are of value afterwards.

Dr Jones

167. Could I ask what your view is of PPARC's claim that their scientists are widely employable outside the PPARC areas once they have completed their PhDs and post-docs, and how is this different from other disciplines?

(*Professor Gunn*) I am afraid I can only be anecdotal about this, I do not know the statistics, but it strikes me that there are two things which are particularly true of the PPARC manpower, meaning people who have done PhDs or post-doctoral research fellowships. The first thing is that they usually have experience of working right at the leading edge of information technology and computing equipment and that certainly makes them quite marketable. The second aspect is that the experimental ones, at least, have had experience of working in very big teams, and this is something which, if you listen to industrialists, they always stress as being a very desirable quality to have in people who are produced by higher education, and really it is *par excellence*, that sort of thing. So teamwork and expertise in IT are two things you can highlight as being particularly true there. On the other hand, I would not want to do down my own area. My own research students, again to be anecdotal, have also ended up being trained quite well in the IT aspects and have found employment in things like banks in the City because of that, but I think it is the teamwork that is probably the unique thing.

(*Professor Donaldson*) I would agree. I think to a large extent the same thing would apply to students in post-doctoral work in a wide range of subjects, but I can say, sitting on committees where we have awarded fellowships to people in competing fellowships across different subjects, the quality of people doing particle physics work is extremely high.

168. But in fact a smaller proportion of PhD students actually go into industry. Does that mean we are not producing enough of the students that industry would like to take up if they are so valuable?

(*Professor Donaldson*) A smaller proportion than undergraduates.

169. Apparently only 24.4 per cent. of PhD students go into industry, which is fewer than other Research Councils, and yet the argument is that they are becoming very marketable?

(*Professor Gunn*) Is industry distinct from commerce here?

170. I have no idea. It is what they say in their Annual Report.

(*Professor Gunn*) The reason I make that distinction is that I know a lot of people on the more theoretical side and mathematical side go into the financial sector, which might not be included in the term "industry".

Dr Jones: I think it probably does.

Dr Bray

171. It must include it because the manufacturing would be 0.5 per cent.

(*Sir William Mitchell*) There is, I think, a difficulty about this argument. I believe the PPARC statement. Their people are highly employable, for the reasons that Professor Gunn has mentioned, and that is very good. I do not think you can argue that you have to spend money on particle physics for that specific purpose and I have had discussions in the past, not in connection with this but with one of your assessors, who has clearly said that, of course, there are other ways of producing training in terms of IT and in terms of teamwork. So, although I absolutely agree with the PPARC statement that they are employable people, one cannot go on that, therefore, that is a leading factor. It is like the spin-off. It is a very good factor. What would be terribly sad and impossible is if they were unemployable. On the contrary, they are very employable and within those limits I would feel you have to be a little bit restricted.

Mr Bruce

172. I was just going to say—and I am really disagreeing with Sir William now in saying this—that surely it is a lot easier to prove that we get really good scientists and really good people back into industry and commerce and everything from all the work you do in particle physics than it is to prove that the quark really exists, but I am just being controversial.

(*Sir William Mitchell*) No, I think you do get good people, but maybe those people would be good in other ways.

Dr Bray: May we thank you all for giving evidence. You have been proof positive that there are people outside full-time employment in particle physics who are interested in the subject. Thank you for that and many other contributions you have made to our work. Thank you very much.

WEDNESDAY 1 MAY 1996

Members present:

Sir Giles Shaw, in the Chair

Mr Spencer Batiste	Sir Trevor Skeet
Dr Jeremy Bray	Mr Patrick Thompson
Mrs Anne Campbell	Sir Gerard Vaughan
Dr Lynne Jones	Dr Alan Williams

Memorandum submitted by the Particle Physics and Astronomy Research Council (12.96)

1. Preamble

The Particle Physics and Astronomy Research Council (PPARC) welcomes this Inquiry by the Committee, which will provide a valuable forum for a wider debate of the key issues facing the Council, in particular those arising within a science programme dominated by several major international partnerships.

2. Introduction

2.1 The PPARC is a non-departmental public body funded by Parliamentary Grant in Aid frôm the vote of the Office and Science and Technology, DTI. Its formation was announced in the 1993 White Paper "Realising our Potential" which set out its mission as:

> "to promote and support high-quality basic research and related post-graduate training in astronomy, planetary science, and particle physics, which takes account of the potential for contributing to the United Kingdom's industrial competitiveness and quality of life, but whose main objective is the improved understanding of the concepts and principles underlying physical phenomena and their consequences."

2.2 It was subsequently granted a Royal Charter which established it with effect from 1 April 1994 as a Research Council within the meaning of the Science and Technology Action 1965.

2.3 The PPARC leaflet "Research at the Edge of Knowledge" provides a convenient summary of the work of the Council. (Copies supplied to the Committee). The Council's first Annual Report was laid before Parliament on 4 December. (Copies supplied to the Committee).

2.4 PPARC is a relatively small Research Council, with well focused remit, oganisation and delivery. It maintains a small infrastructure. Experience is showing this to be an advantage over the previous arrangements. PPARC achieves its objectives by

- support of major international facilities in particle physics (the European Laboratory for Particle Physics, CERN) and space science (European Space Agency, ESA) through intergovernmental subscriptions (54 per cent of budget in 1995–96);
- development of new instrumentation to maximise the scientific return from the above facilities (11 per cent);
- development and support of competitive domestic or shared facilities (mainly ground-based telescopes and radars (16 per cent);
- provision of grants to university scientists for research using data from the above facilities and for related theoretical studies (15 per cent);
- provision of studentships and fellowships (4 per cent)

as well as more recently developed activities in the Public Understanding of Science (about £200k pa and promoting industrial benefits (£300k).

The piechart at Figure 1 shows this division of funding in 1995–96.

2.5 PPARC (together with the Higher Education Funding Councils) provides the only significant source of national funding for the scientific disciplines it covers. There are currently no major industrial, charitable or foundation sources of funds for these basic research fields. PPARC thus has a unique responsibility, which distinguishes it from the other Research Councils—for most of whose subjects additional funding sources exist. The biomedical and life sciences, in particular, benefit from very substantial funding from the multinational pharmaceutical companies, and the major medical research charities, the latter having a larger combined budget than the MRC. The chemical, environmental and engineering sciences also benefit from more alternative funding sources. Recent initiatives for additional public funding, such as the ROPAs, have also notibly not benefited physics researchers, in part, rather perversely, because basic physics research is not as "near-market" as some areas more successful in winning ROPA funds.

The long term nature of PPARC research

2.6 Planning for research in most PPARC areas is essentially long-term. From the initial concept of a space mission or major particle physics experiment to the eventual collection and interpretation of the first data can often take 10–15 years. Firm commitments can be required for at least 10 years ahead (as in the case of the Large Hadron Collider (LHC) being built at CERN). Complex international agreements, eg, to build space instruments, cannot easily be broken. With such timescales and international commitments the need for funding stability is of particular concern to PPARC.

The international quality

2.7 Because of its cost much leading research in particle physics and astronomy can be done only in international collaboration (see also below). PPARC is reassured that the quality of its own research programme is constantly judged by international standards. The National Audit Office (NAO) is finalising a report on performance indicators for PPARC which will suggest a number of quantative ways in which the international quality of our research output can be measured objectively. We already have evidence to show that UK research productivity in most PPARC areas exceeds that of our major competitors.

3. The Science Programme

3.1 The PPARC mission is to address some of the most fundamental and challenging questions that have puzzled and motivated mankind throughout history:

- what are we made of?
- how was the universe created?
- how will it end?
- what lies beyond the earth?
- what are stars and how do they work?
- are there other planets like the Earth?

The continuing contribution of our scientists in addressing these questions is reflected in the high esteem that Britain is held overseas by other technologically advanced countries. Without it, Britain's involvement in applied scientific research will be weakened lacking the knowleged, facilities and (vitally) the expertise of our scientists. Fundamental physics has been consistently shown to be the science that most intrigues and challenges students; ensuring Britain a rich crop of future scientists, in all disciplines.

3.2 Once these questions were the province of the philosopher or amateur astronomer equipped only with a sharp eye or simple telescope and astrolabe. They are now addressed by huge machines or complex facilities that stretch the financial and intellectual resources of even the richest nations, but still have a vital role for individual theorists, such as Stephen Hawking, who draw on the discoveries made in these international endeavours. It is important to recognise that astronomy and particle physics are fields in which the UK has a long and proud tradition from Newton and Halley to Eddington and Hoyle, and is set to celebrate a century of discovery in atomic physics, from the identification of the electron (by J J Thomson), the nucleus (Rutherford), and the neutron (Chadwick), to the successful prediction of positrons by Dirac, and the favoured mechanism responsible for mass proposed by Peter Higgs.

3.3 These questions address issues on every scale, from the most basic sub-atomic particle (the quark), to the incredibly vast distances of the universe; reaching back in time and space to the original creation in the "Big Bang"; and including the intermediate scale of the Sun, the Earth, and solar system and our neighbouring stars.

3.4 The Council's publications supplied to the Committee, "Research at the Edge of Knowledge", "Big Bang Science" and "Our Solar Connection", provide introductions to the science. The following paragraphs summarise key points.

Particle Physics (see leaflet "Big Bang Science")

3.5 Particle physics addresses the nature of matter—"what are we and all else made of"—at its fundamental level. The goal is to describe the ultimate nature of matter, and its behaviour, through the fundamental laws of physics. From the early belief that the atom was the smallest, indivisible particle, colliders of increasing energy have now uncovered the subtle complexity of sub-atomic matter suggesting that all matter is built up from two families of elementary constituents:

— quarks (which make up the proton and neutron)
and — leptons (including the electron)

These interact through four fundamental forces: gravity, electromagnetism and the strong and weak "nuclear forces".

3.6 It is a considerable triumph of post-war research, led by the USA and Europe, that physicists are now able to describe the nature and interaction of these basic particles according to the theory known as the "Standard Model". Current research at CERN's biggest accelerator, the (16 mile track) Large Electron Positron Collider (LEP), is now refining the details of the Standard Model and the properties of the family of quarks. Major challenges that remain include finding explanations of why matter dominates over "anti-matter" in our Universe, and the "origin of mass".

3.7 The greatest promise for future progress depends now on using the greater collision energies which will be provided by the planned CERN Large Hadron Collider (LHC). Since hadrons, including the proton and anti-proton, are much heavier than the electron or positron, their collisions involve more energy than in the LEP. The LHC will allow a range of new experiments and, in particular, will address the key issue of why particles have mass (why are things heavy), and whether this is due to the "Higgs" particle (or boson) as predicted by the Edinburgh University physicist, Peter Higgs. Following the cancellation of US super-collider project in 1993, the LHC has become the outstanding new initiative in particle physics, on a world scale. In turn, it confirms CERN as the leading centre for high energy physics research, providing unique opportunities for UK scientists to remain actively involved at the "cutting edge" in this fundamental branch of science for 15–20 years ahead.

Solar system science

3.8 Solar system science is concerned with the structure and behaviour of the Sun, the planets and minor bodies, such as comets and asteriods. Issues of particular interest are to understand the influence of the Sun on our Earth and what can be learned about the formation and evolution of the Earth from studies of the other planets and minor bodies.

3.9 The Sun is effectively a giant nuclear fusion reactor, which converts hydrogen into helium, generating the energy which, among other things, is essential to life on Earth. But far from being a simple furnace, the Sun is a highly complex system. Solar research addresses what happens inside the Sun; how the heat is transmitted from the centre to the outside; and the nature of the huge electrical and magnetic storms on its surface, which we identify with solar flares and sunspots.

3.10 The ESA spacecraft Ulysses, launched in 1990 and carrying several UK instruments, is currently obtaining unprecedented data on the Sun by flying successively over its south and north poles—gaining views impossible from Earth's orbit round the Sun's equator. UK X-ray experiments on the Japanese satellite Yohkoh are also contributing to our knowledge of the Sun's magnetic activity. In 1996 the latest ESA satellite, SOHO (Solar Heliospheric Observatory), also carrying UK instruments, will begin a detailed study of the Sun and its influence on Earth, from a unique vantage point balanced between the pull of the Earth and our parent star.

3.11 This research is important both in informing us how stars in general work (and could change), but also because of the direct impact on the Earth of the so-called solar wind, a stream of energetic particles which boil off the Sun's surface and hit the outer atmosphere at supersonic speeds. Magnetic activity on the Sun produces surges in this particle stream which are known to cause the visible aurora (Northern lights), disrupt electrical power and radio transmission systems, and influence the terrestrial weather in ways not yet fully understood.

3.12 The next year will see major advances in this field. In summer 1996 the ESA/NASA project "Cluster," will see four identical spacecraft, again with UK instruments on board, launched into the Earth's outermost atmosphere, where they will fly information, so as to build up a three-dimensional picture of the solar wind as it impacts the environment around the Earth. Operating in parallel with SOHO, the Cluster spacecraft will be able to relate these impacts directly to activity on the Sun one to two days earlier.

3.13 Co-ordinated studies of related effects, still closer to the Earth's surface, will be made by an array of ground-based radar transmitters and receivers, including EISCAT (The European Incoherent Scatter Facility), a UK-German-French-Scandinavian collaboration. These radars are concentrated near and inside the Arctic circle where solar activity effects are most severe and communications and other human impacts likely to be greatest.

3.14 Comets are thought to contain some of the most primitive material in the solar system. Their study should yield information on the Earth's early history. Following the outstanding success of the ESA Giotto spacecraft (with UK instruments, and prime contractor British Aerospace) interception of Halley's comet in 1986, the same spacecraft (remarkably little harmed) was re-routed to intercept another comet, Grigg Skellerup, in 1993. The next major opportunity for a cometary encounter, including direct sampling, will be the ESA "Rosetta" mission, scheduled for launch early next century, in which UK scientists are set to be involved (funds permitting).

3.15 Research on the major planets has traditionally been dominated by the USA and Russia. However, UK university groups have contributed successfully to planetary (particularly Martian) geology and climate studies and researchers at Oxford, Kent and Imperial College are involved in the current Galileo Jupiter mission. The UK will make a larger contribution to the major NASA/ESA 1997 mission, called Cassini/Huygens, scheduled to orbit Saturn and to release a probe onto the surface of its largest moon, Titan. Titan is of similar size to the Earth, and has an atmosphere which may resemble that of the early Earth, before life emerged. Again this mission offers important potential for yielding clues to the origins of life.

Cosmology, astrophysics, stars and galaxies

3.16 Far outside our own solar system, research addresses the fundamental question of how the "Big Bang", 10–15 billion years ago, produced the structural universe of today, with its giant clusters of galaxies, themselves huge collections of stars at different stages of life, and including the many mysterious objects such as black holes and pulsars.

3.17 Current research in cosmology ranges from theoretical studies of the earliest moments (billionths of a second) of the Big Bang, through the study of the large scale structure of the evolving universe to the search for the invisible or "dark matter", which apparently dominates the total matter in the universe. Questions in astrophysics include the origin and power sources of galaxies with active nuclei, and the life cycle of stars, from their birth in clouds of interstellar dust, through their active phase (like our sun), to their ultimate collapse into an incredibly dense white dwarf or neutron star, or the even stranger "black holes" from which not even light can escape.

3.18 Until about 50 years ago astronomers' knowledge of the universe depended on what could be seen with the aid of ground-based telescopes operating in the visible or optical band of the spectrum—and this remains a key source of information. But the last few decades have seen astronomy revolutionised by the development of techniques to study the stars and galaxies at wavelengths invisible to the human eye, from radio and infra-red waves to the much shorter ultra-violet, x-rays and gamma rays. In addition, while radio waves and visible light pass easily through the Earth's atmosphere, most other wavelengths are absorbed by the atmosphere and their information remained hidden to astronomers until the era of satellites.

3.19 Major advances in astronomy, today, depend on combined observations in as many different wavelengths as possible, and thus need access to a range of different types of telescope. The UK, as an early pioneer in many of these new techniques, is fortunate in having that breadth of access.

3.20 The main means of observing in the visible, millimetre and near infra-red ranges are the site of telescopes on La Palma (William Herschel 4.2m; Isaac Newton 2.5m and Jacobus Kapteyn 1m) and Hawaii (UK Infra-Red Telescope and James Clerk Maxwell millimetre wave telescope). Around the turn of the century, these will be enhanced and complemented by the twin 8 metre telescopes of the US/UK/Canada Gemini project—one for the northern hemisphere on Hawaii, one for the southern, in Chile.

3.21 The power of space-based visible waveband astronomy is currently being demonstrated by the Hubble Space Telescope (HST), to which Europe contributed a key instrument, the Faint Object Camera (conceived by a UK astronomer). UK astronomers have consistently won the largest share of observing time on the HST.

3.22 Radio astronomy continues with the giant Lovell, and other telescopes at Jodrell Bank, and at the Cambridge Mullard Observatory, observing phenomena such as "pulsars" and radio jets, and increasingly uses telescopes linked together to give greater resolution by the technique of interferometry—as in the MERLIN (Multi-Element Radio-Linked Interferometer Network) project—which has a resolving power comparable to the Hubble Space Telescope.

3.23 Far infra-red astronomy, sensitive to cool matter such as the dust from which planets may be formed, has depended largely on data from the 1980s UK/Netherlands IRAS (Infra-Red Astronomy) Satellite. Henceforth this research will be greatly enhanced by the much more powerful Infra-red Space Observatory (ISO), launched by ESA in November. UK astronomers have provided one of the four ISO instruments, and have won the largest share of competitive observing time of any nation (including the USA).

3.24 Ultra-violet observations are made primarily with the International Ultra-violet Explorer (IUE), a UK inspired mission now in its 18th year of operation. Moving to still shorter wavelengths, the UK was a pioneer in the rich field of X-ray astronomy, which yields information on regions where very high temperatures dominate, such as in binary star systems where gas is drawn into the high gravity close to a neutron star or black hole, or in the debris of a recent supernova (or exloding star). Currently, X-ray observations are made with the German/US/UK "Rosat" satellite and the Japanese ASCA mission, in which UK scientists are also actively involved.

3.25 X-ray astronomy in the 10–15 years ahead will be continued and enhanced by the powerful JET-X (Joint European Telescope) instrument, scheduled to fly in 1997 on the Russian Spectrum-X mission, and by the major ESA Cornerstone mission X-ray Multi-Mirror (XMM), both including instruments developed by UK university groups. A UK-led consortium, also including researchers from France and Germany, was recently chosen by ESA to lead the scientific exploitation of the 10-year XMM mission.

3.26 Gamma rays have the shortest wavelengths and hence the highest energies in the electromagnetic spectrum. They are normally quite rare and are difficult to detect. In 1994 PPARC announced that it was unable to support direct UK involvement in the ESA gamma ray mission INTEGRAL (the International Gamma Ray Laboratory), due for launch in 2001, a particularly disappointing outcome as UK scientists had taken a leading role in the design of the mission.

The ESA Ministerial Conference

3.27 The recent (October 1995) Ministerial Council of ESA in Toulouse was of key importance to the future of space science in Europe. It confirmed the continuation of the long-term planning framework, Horizon 2000, and endorsed the broad framework of its successor programme Horizon 2000-plus. Both these programmes had a substantial (more than pro-rata share) UK input in their formulation, and both offer a stable forward plan of missions of interest to UK scientists. Ministers' agreement to a revised funding envelope, requiring annual efficiency savings of 3 per cent pa, will help (though not guarantee—see below) PPARC's ability to support UK involvement in these future missions.

Possible future avenues of research

3.28 PPARC is concerned that through lack of funding it is currently unable to invest at an acceptable level in the future CERN and ESA programmes, or in any significant new facilities and instruments required to exploit exciting new areas starting to emerge (see also below Section 7). Without these investments the subjects themselves will inevitably decline in the UK over time. For example, outstanding research at Glasgow and Cardiff universities, and elsewhere, suggests that it should soon be possible to detect the gravitational waves predicted by Einstein's General Relativity Theory, by using lasers to measure the tiny contraction and expansion in the space between two masses. Such a technique will enable a whole new range of astronomical phenomena to be studied. The opportunity exists for a UK-German collaboration to build such a detector, but PPARC funding constraints have meant that the UK can participate—at best—at only one third of the level originally envisaged.

3.29 A second priority project involves Cambridge radio astronomers who have a working prototype of a device to map the microwave radiation which fills the universe as a distant remnant of the original "Big Bang". The US COBE satellite's evidence of such structure caused headline news three years ago. The opportunity now exists to refine these results so as to see the structures from which present-day galaxies must have formed. Regrettably, to date, PPARC has been unable to fund the £2-3 million investment to enable UK radio astronomers to exploit their world class expertise in this highly topical and important field.

3.30 Thirdly, the possibility now exists of detecting directly a type of particle which might account for the missing "dark matter" in the universe, whose existence is inferred, for example, by the movement of stars in galaxies. An experiment using sensitive detectors, deep underground in Yorkshire, is giving promising results, but needs further funding to achieve definitive sensitivity levels.

PPARC is currently maintaining a strong science programme in particle physics, planetary science and astronomy, but these opportunities are based largely on the earlier investments by the SERC. Severe funding pressures on PPARC's domestic budget is now limiting future investment which will increasingly threaten the health of these research communities into the next century.

4. INTERNATIONAL COLLABORATION IN PARTICLE PHYSICS AND ASTRONOMY

4.1 This section responds to the Committee's general interest in the issues of international collaboration and addresses the specific questions posed in the Press Notice of 19 October.

4.2 As noted already the scale and cost of modern particle physics, space science and most astronomy now stretches the resources of even the richest nations. International collaboration, therefore, is the only way for the UK to keep its place in research fields which it helped pioneer. It is thus essential that the UK continues to participate in the Large Hadron Collider if it is to retain a significant future world role in particle physics.

4.3 Given their cost, these collaborations require the engagement not only of funding agencies such as PPARC, but also of their parent governments. Both CERN and ESA are founded on intergovernmental treaties. Because of the scale and complexity of the facilities concerned they have planning and construction lead times of 10-15 years, which require long-term commitments from Governments.

4.4 On the basis that participating nations should contribute equitably according to their national wealth, for both CERN and ESA, member state contributions are calculated from their respective GDP or NNI (Net National Income). The willingness of governments to fund domestic programmes at the level required to derive benefit from those subscriptions is then assumed.

4.5 Three factors cause particular problems for PPARC (and the UK):

(a) Alone among member states, the UK has traditionally funded its intergovernmental science subscriptions from the same budget as the funds needed to exploit those subscriptions. While this funding method has logic, the effect has been that, as subscriptions have risen, the supporting domestic budgets have been cut—thus reducing the scientific community's ability to exploit the subscription to the maximum benefit of UK science.

[Although their systems differ in detail, France, Germany and Italy traditionally fund the domestic exploitation of international programmes from different budgets than the subscriptions themselves, and in consequence the domestic programmes have been better protected from movements in those subscriptions].

(b) Partly as a result of (a), the UK has traditionally been constrained to a lower ratio of domestic programme to international subscription, as compared with our main "competitors". For space science, according to the latest ESA data, the UK ratio is now 0.35 compared to between 1.1 and 1.3 for France, Germany and Italy. For particle physics the most recent data from CERN suggests that indicative figures are UK 0.35, France 1.25, Germany 1.5 and Italy 1.1. (The bar charts at Figure 3 include total domestic spend and show therefore a somewhat higher ratio.)

(c) Our CERN and ESA subscriptions are denominated in Swiss francs and ECU respectively, both of which have appreciated against the pound. While, over time, the calculation of national subscription rates should take account of relative currency movements, in the short term the depreciation of the pound against these currencies can require significant additional funding. Specifically, the cost of CERN to the UK has risen by £16 million (some 29 per cent) since PPARC was formed, despite the fact that CERN's budget in Swiss francs has remained essentially constant in real terms.

4.6 Recognising the difficulties that such short term fluctuations could cause PPARC, the Government announced in the 1993 Science White Paper (para 6.17) that "The Director-General of Research Councils will be asked to bring forward proposals for handling this within the science budget as a whole, so that the Council does not have to cope entirely within its own grant-in-aid with short-term variations in international subscriptions which rise for reasons beyond its control." This mechanism was introduced and applied in 1994–95 when the OST assigned a sum of £8 million to PPARC, which was ring fenced for the purpose of paying the additional costs of the CERN subscription that year.

4.7 The Minister for Science, Ian Taylor MP, has subsequently reconfirmed the Government's commitment to these principles. But, the scale of the current appreciation of the Swiss franc this year will again impose a significant burden amounting to about £10 million, on the Science Budget as a whole, affecting all the Research Councils. For PPARC, its "share" of this would be on a pro-rata basis £1.7 million. This could be found only by further reducing our ability to exploit our investment in subscriptions and facilities. More significantly, the pressure on the Science Budget arising from increases in international subscriptions is again likely to leave little support for funding to strengthen PPARC's domestic research programme.

4.8 In the 1993 White Paper (para 6.17) the Government addressed the issue of whether the funding of international subscriptions should be taken outside the science budget of the (then) OPSS. It stated that "In the Government's view it is important for such subscriptions to be seen as part of our scientific endeavour rather than our foreign policy. Decisions on relative priorities must be taken in the context of the science budget".

4.9 The Government's response to the House of Lords Report on International Investment in UK Science (session 1993–94, 4th Report, HL 36-I) re-affirmed the Government's recognition that international collaboration in science is continuing to grow, and their agreement that . . . "we must seek to ensure that this country remains a sought-after international partner . . ." Subsequently, the value of high profile UK research activities in changing the image of the UK has been widely recognised, with potential benefits to inward investment and the UK "education industry".

4.10 Given this clear commitment by Government, coupled with the reduced ability of PPARC to exploit the Government's investment in international subscriptions, the resultant loss of value for money, and the strains this imposes on relations with international partners, **the Committee may wish to consider the advantages and disadvantages of alternative ways of funding international subscriptions,** taking particular account of the experience of other countries in this area.

The international management of major projects

4.11 The PPARC is satisfied with the present international management of the CERN and ESA programmes, with contributions based on GDP or NNI, and management and control by an overall Council of government representatives, with a series of delegate bodies. Within the UK, the arrangements for co-ordinating briefing for UK delegates (via the British National Space Centre for ESA; and via the UK CERN Committee run by OST) are in general satisfactory and work well.

4.12 However, we are not convinced that the potential for more cost-effective and efficient procedures in both ESA and CERN has been fully exploited. In both cases significant progress has already been made—mainly at UK instigation.

4.13 In the case of CERN, the improved procedures arising from the "Abragam" review in 1987, called for by the UK, resulted in a revised method of calculating member state contributions, and significant improvements in financial and human resource management, leading to a more efficient, leaner organisation. The LHC approval in 1994 constrained CERN to zero inflation compensation for three years and 1 per cent thereafter. In ESA, a similar review of the Science Programme, also called for by the UK, the Pinkau review, produced increased value for money (or "purchasing power") to the benefit of the Science Programme of around £14 million pa. This substantially reduced the pressure to increase subscriptions being sought by ESA in order to develop the Horizon 2000 programme.

4.14 More recently, as noted above, at the ESA Ministerial Council in Toulouse, the UK successfully led a move to cap the Science Programme Budget, by allowing no compensation for inflation, if under 3 per cent pa, for each of the next five years. This will require ESA to make efficiency savings of around 15 per cent. In parallel, a series of efficiency measures were agreed which will improve the cost-effectiveness of the whole organisation. (More details could be supplied to the Committee on request). As part of the UK/BNSC delegation, PPARC will be vigorous in following these up.

4.15 In relation to CERN, PPARC is already in dialogue with OST and with CERN top management on ways of further reducing the subscription by cost-saving measures. CERN recognise that the significant appreciation of the Swiss franc has increased CERN's purchasing power, by reducing the cost to CERN of goods and services bought from member states whose circumstances have depreciated relative to the Swiss franc.

4.16 The current review of CERN salaries provides an important opportunity to examine the scope for futher reductions. These approaches will continue to be vigorously pursued by PPARC.

4.17 But while efforts to increase efficiency are essential, and will be pursued by PPARC with the OST, they cannot alone redress the long-term underlying and increasing inability of PPARC to back up the international subscriptions with a vigorous supporting domestic programme.

International programmes increasingly dominate the PPARC agenda. These are—by definition—of very high quality, but their long-term nature requires stable funding to ensure a good return on UK investment.

5. DETERMINATION OF PRIORITIES: THE ROLE OF COUNCIL AND COMMITTEES

5.1 As defined in its Royal Charter, the Council of PPARC comprising the Chairman, Chief Executive and ordinary members, is the supreme executive body of the PPARC. As such it determines overall strategy, and defines the broad framework and key priorities for PPARC. Day-to-day management and financial authority up to a specified limit is delegated to the Chief Executive, Professor Ken Pounds and his staff.

5.2 The Council set up four advisory committees or panels to advise on:

- Audit (currently chaired by Dr Sue Ion, member of Council);
- Education and Training issues (chaired by Professor John Enderby, member of Council);
- Industrial collaboration (chaired by John Ashton, EEV Ltd). (This panel has now completed its primary task of submitting a report to Council, and will be replaced by a new body to oversee its implementation—see below paras 6.7 to 6.11);
- Public Understanding of Science (chaired by Professor Sir Martin Rees, member of Council);

5.3 Scientific peer review is led by the two science committees:

- Astronomy, including solar system science (chaired by Professor David Williams);
- Particle Physics (chaired by Professor David Saxon, until 31 December 1995; thereafter by Professor Brian Foster);

who advise the Chief Executive. These committees provide the more detailed scientific advice on the balance of funding between the different elements of their respective science programmes; and give guidance to the grant awarding bodies. The Council is thus provided direct, or via the executive, with the advice it needs to determine its overall strategy and broad priorities; and having determined those priorities, the means to carry them out.

6. THE STRATEGIC TARGETS

6.1 The Council's first Corporate Plan (copies supplied) set out its broad objectives under the five themes of:

- Research
- Trained Scientists and Engineers
- Industrial competitiveness
- Promotion of Science
- Operational Effectiveness

6.2 More details on these are given in the Corporate Plan, and the Council's first Annual Report reports on progress under each heading.

The Council's "new targets"

6.3 In its first year the Council recognised the long-term decline in the funding for its areas of science. It held a Strategy Weekend in July 1995 at which it agreed to argue the case for a reverse in the decline of funding for its areas of science on the grounds of their inherent intellectual importance, their value in training skilled manpower, their role in attracting young people into science, and their significance in the development of leading edge technology of potential commercial value to UK industry.

6.4 The Council accordingly resolved to set a strategic target of increasing its PhD studentships by 50 per cent and to increase its efforts in the public understanding of science and the development of industrial benefits of its programme. It also accepted the target of a re-balanced research programme, with not more than 50 per cent of its funding being committed to international subscriptions. The following gives more detail on these initiatives.

Trained scientists and engineers

6.5 The Council regards its output of skilled scientists as one of its major contributions to the nation. While the intellectual challenge of particle physics and astronomy continues to attract a high proportion of First Class physics and maths graduates, successive studies have demonstrated that on completion of their PhDs these individuals have the skills sought by employers (communication, problem solving, initiative, team working), and that they enjoy a very low unemployment rate within a few years of completion (PIEDA study 1995—copies available).

6.6 The Council's Education and Training Committee took these findings into account in their report (copies supplied to the Committee) which, *inter alia,* recommended an increase of some 20 per cent in the number of studentships awarded, and the development of a closer relationship with post-graduates to ensure a consistently high and relevant quality of training experience. The Council subsequently, as noted, set an even more ambitious strategic target of a 50 per cent increase in studentships.

PPARC intends further to develop relevant data on the value of the postgraduate training it supports, to work with other bodies (eg. the Institute of Physics, universities and industry) to optimise overall training, and set appropriate new levels of funding.

Industrial Competitiveness

6.7 The history of science and technology shows how often a technology developed for pure research is subsequently developed for a (sometimes quite unconnected) practical application. Several recent case studies are given in the leaflet "Helping Industry—the application of PPARC—funded research" (supplied to the Committee).

6.8 The detection and interpretation of faint signals from distant galaxies, the detailed exploration of the solar system and the detection of elusive sub-atomic particles, all require engineering, technology (telescopes, accelerators, spacecraft), software and instrumentation pushed to its limits. Some 80 per cent of the Council's research funds are spent on such technology and its development. This is a field of "precision engineering" in which the UK excels—one reason for the attractiveness of UK groups as partners (in space missions, particle physics collaborations, or advanced telescopes).

6.9 The case studies demonstrate that there is already significant technology transfer from the PPARC science programme into industry. The Council is determined to increase this. In its first year it launched a new scheme to support industrial collaboration—the PPARC Industrial Programme Support Scheme (PIPSS)—which attracted a high level of interest. Despite a short deadline some 47 applications were received from some 25 different industrial companies and a similar number of academic groups. The list of successful awards, included in the Annual Report, indicates the range of topics and companies covered. A second round of PIPSS, completed more recently, resulted in a similarly strong response.

6.10 In parallel the Council has been advised by its Industrial Liaison Panel (50 per cent industrial—50 per cent academic members) on a number of ways to enhance industry's awareness of novel technology generated in the Council's programmes and how to increase further its flow into industry. These range from the development of a long range technology plan to the support of industrial PhD training such as an enhanced CASE (Co-operative Awards in Science and Engineering) scheme, and use of the Internet to spread awareness of university technological expertise. (Copies of the full report available on request).

6.11 At its Strategy Weekend the Council resolved to increase its efforts to enhance the industrial benefits of its programme, and plans are now under way to implement this, with advice from a new Industrial Policy Advisory Committee, successor to the ILP.

PPARC is committed to enhancing the partnership between its academic community and physics-based industry, in order to gain maximum industrial benefits from its research programme.

Promotion of Science

6.12 Personal experience, anecdotal evidence and successive studies testify to the attraction which astronomy and space (and to a lesser extent particle physics) hold for young people—as well as the public at large. This gives PPARC a particular opportunity, and a national responsibility, to use that attractive power to encourage more young people to study science. The Council has agreed to increase its efforts to do this, in line with Government's own increased emphasis on the public understanding of science.

6.13 In its first year the Council set up a panel to advise it on its public understanding of science (PUS) policy and programme, under the chairmanship of Professor Sir Martin Rees FRS, Astronomer Royal and President of the British Association for the Advancement of Science (BAAS). The Panel comprises members from the academic, teaching and media sectors. The Chief Executive also conducted a personal survey of the PPARC academic community which revealed both the extent of existing PUS activity in universities, and the potential to do more, particularly with schools, given only relatively modest funding.

6.14 The Council accordingly agreed on two immediate initiatives. First, that all PPARC grant holders in universities would be entitled to spend up to 1 per cent of the value of their grants on PUS activity—a policy subsequently endorsed in the Wolfendale report on PUS. Secondly, a Small Awards Scheme was set up, to make awards up to a maximum of £10,000, available to anyone—schools, universities, societies—offering a novel way to present PPARC science to schools or the general public. The scheme was heavily over subscribed and the first awards, announced at the British Association in September 1995, included funds for a new radiotelescope at Taunton School, (made widely accessible via Internet), the involvement of a rock group in a science event for young people at Jodrell Bank, and the development of a remote robotic optical telescope for schools. (A copy of the full list of awards is available.)

6.15 A similar scheme will be run next year, as part of an enhanced Schools PUS programme, which will also build on the Lunar Samples programme, in which PPARC loans out samples of original moon rock, provided by NASA. PPARC is also collaborating with the EPSRC in a major (£1 million) initiative to develop curriculum material for schools—the Pupil Researcher Initiative.

PPARC will continue its wider role, working, primarily through its research community, to enhance interest in and understanding of the physical sciences throughout the UK.

7. FUNDING ISSUES—SUMMARY

7.1 The underlying causes of PPARC's financial difficulties are:

- the long-term rise in the proportion of our budget committed to international subscriptions;
- the inheritance, from SERC, of a rich programme of opportunities, but with insufficient funds and flexibility to meet them;

- Council's wish to enhance the PPARC programmes in Education and Training, Public Understanding of Science, and Industrial links;
- the failure, so far, of any additional bids to Government for new funds (with the exception of a ring-fenced allocation for CERN exchange rate variations), including funds to offset the effects of inflation on a cash-limited budget.

The central underlying concern is our inability to invest in the future, in the next generation of students, of new projects and the infrastructure of our university groups. Past investment by SERC is currently offering the PPARC comunity a rich harvest of exciting data from experiments on LEP, key space missions (Ulysses, ISO, SOHO/Cluster) and a suite of ground-based telescopes and radars. But unless we are planting now the seeds of future research facilities, there will be no such harvest for the next generation. In addition, present funding difficulties threaten the full exploitation of current science data.

7.2 Physics research played a major role in the last war and this was reflected in the levels of funding for fundamental research which the discipline enjoyed in the ensuing years. Since then there has been a progressive decline, not only in its percentage share of the Science Vote (due partly to the expansion of support for engineering and biological science) but, also in its absolute level in real terms. Figure 2, attached, shows these trends over the past 20 years. Despite an increase of some 53 per cent in real terms in the total UK spend on science, total expenditure of particle physics and astronomy has fallen in real terms by 32 per cent, while the domestic programme has fallen by 53 per cent.

7.3 Over the same period, the rising cost of research in these fields has meant an increasing dependence on international collaboration, as already noted. The UK was a founder member of CERN and a leading player in the subsequent creation of the European Space Research Organisation (ESRO) (orignially inspired by the success of CERN), which in 1974 merged with the European Launcher Development Organisation (ELDO) to become the European Space Agency (ESA). The proportion of the total UK nuclear (including particle) physics budget spend on the CERN subscription rose from about a quarter to about two-thirds in 1995–96.

7.4 Over this time the cost of the UK contribution to such organisations has also risen steadily in real-terms, a significant factor being the decline of sterling against other European currencies. Whilst in the last two years the OST has offered some protection against these fluctuations (at the expense of the science vote as a whole) the additional cost of the subscriptions has had a knock-on effect which has exacerbated the underlying decline in the funding for particle physics and astronomy and planetary science. Figure 3, attached, shows how the overall ratio of domestic to international spend on research has declined since 1975–76.

7.5 While increased reliance on international collaboration inevitably entails some increase in the percentage of the budget spent on international subscriptions, there is an upper limit beyond which value for money cannot be maintained. That limit has now been exceeded for both particle physics and space science.

7.6 The consequences are:

for particle physics:	UK scientists will be able to participate in the next generation of experiments on LHC at a level only perhaps of half of that which would be justified by the size of our contribution (which is based on our relative GDP). This, necessarily, will fail to give full value for money for our contribution. An additional £8 million per annum is required to ensure a participation level which would give an optimum return on our investment;
for space science:	(a) the UK has already had to decline payload opportunities in the next ESA astronomy mission (the gamma ray observatory INTEGRAL) despite UK scientists having played a leading role in its conception and planning. Apart from the loss of UK science, this will necessarily result in reduced value for money from our ESA science subscription;
	(b) on present plans the UK seems likely to be able to participate in future ESA missions at only around half the level justified by its subscription. An additional £5 million per annum would allow the UK to achieve a more optimum scientific return on its investment.

7.7 Given their scale the Council is unable to redress these imbalances from its own resources. The only other significant element in PPARC's budget is the ground-based (mainly telescope) research budget. This has now been reduced to a level at which it is projected that it will be possible to invest at only about half the level necessary to sustain the new instrumentation and new projects required for the UK to stay fully competitive. As noted earlier, PPARC's areas of science have few, if any, alternative sources of funding to which to turn.

7.8 The Council has concluded:

- that, on present projections and assumptions, it faces a shortfall of £10-£15 million per annum to maintain full UK competitiveness across the (already selective) range of disciplines required for a balanced scientific programme reflecting and exploiting UK expertise;

— that, in consequence, it must set a strategic target that its International Subscriptions should account for no more than 50 per cent of its **research budget.**

7.9 The Council is currently engaged in discussions with both Government and the relevant international organisations on ways of achieving that target. In particular a bid has been made to OST for additional funds to support the space science (domestic) instrumentation budget to build on the membership of ESA confirmed by Ministers in Toulouse.

8. Other Points, including those raised by the Committee

The 1995 Business Plan

8.1 Preparation for the 1996 Business Plan is currently underway. Its financial planning basis depends crucially on the outcome of this year's Public Expenditure Survey; and on the allocation to PPARC from the Science Budget which the President of the Board of Trade will make in January, on the advice of the Director General of Research Councils. It may, therefore, be more helpful for the Committee to receive a supplementary memorandum from PPARC when those outcomes are known, and PPARC is able to establish the main lines of its 1996 Business Plan. It is hoped that the Plan will include increased funds for space science, enhanced education and training resources; and more funds for industrial collaboration (PIPSS), and Public Understanding of Science.

The effect of Technology Foresight on the Council's Programme

8.2 The OST has accepted that because of the unique nature of PPARC's mission, and the essentially long-term and fundamental nature of its research, it is not expected that the PPARC research programme will be greatly influenced by Technology Foresight.

8.3 On the other hand, PPARC has taken note of the generic priorities established by the Foresight process, in particular its emphasis on the country's need for a highly developed skills base. The Council's strategic target of a 50 per cent increase in studentships directly reflects this.

8.4 PPARC is also taking account of the technology priorities identified by Foresight, in the development of its technology transfer programme. Thus, for example, the field of advanced detectors and sensors was identified as a priority by several Foresight panels, and will be given particular attention in PPARC's developing industrial programme.

The effect of ROPAs and PIPSS on the funding available, and the effectiveness with which research sponsored under such schemes fits into PPARC's research portfolio.

8.5 The ROPAs scheme was devised, led and primarily funded by OST. PPARC cannot judge, for the Science Budget as a whole or for other Research Councils, how far funds for ROPAs have come from new money additional to previous plans, or have displaced Reseach Council funds which would otherwise have been spent on other research. PPARC received a sum of £0.2 million from OST in 1995–96 which was earmarked for ROPAs, although OST agreed that this could be spent on PIPSS if the relative demand and quality warranted it.

8.6 PPARC observes that while the ROPAs scheme rewards existing industrial funding for academic research, it is aimed primarily at encouraging novel academic research rather than explicitly supporting industrial collaboration with universities.

8.7 Given its desire to increase industrial/university collaboration in its field, PPARC accordingly devised its own scheme PIPSS (see also paragraph 6.9 above), designed to foster partnerships between manufacturing companies and academic groups. The quality of bids for the first PIPSS round confirmed that it was meeting that objective; a second round was held in 1995, and the scheme is planned to be further continued. PPARC is satisfied that research sponsored under PIPSS fits in a complementary way into PPARC's research portfolio.

8.8 On the other hand, PPARC received only two applications for ROPAs in 1995, neither of which was judged, by independent assessors, to meet the ROPA criteria established by OST.

8.9 It is a matter of concern to PPARC, and to OST, that overall in 1995 only 13 out of the total 475 awards (less than 3 per cent) went to Physics Departments in universities, compared to 81 for biological sciences, 77 for chemistry, 46 to medicine and 35 to departments "allied to medicine". *De facto* this represents a shift of resources away from physics, and towards the life sciences and chemistry.

8.10 It reflects, and reinforces the traditionally different relationships between the industries in those areas (eg. chemicals, pharmaceuticals) which spend more of their own resources on R&D and directly fund significant research in the higher education sector. Although collaboration exists, sometimes intensively between high tech industries and university physics departments, it is only rarely the subject of direct funding of the academic department by the industry.

8.11 PPARC, with OST, the Engineering and Physical Sciences Research Council (EPSRC) and the Institute of Physics intend to address this issue of the apparent lack of "connectivity" in physics over the coming months.

The ways in which administrative savings have been made to date and are likely to be made in future

8.12 Spend on central administration and programme support has been reduced by 7.4 per cent in the current financial year compared with last. This has been achieved by reductions in the headquarters workforce (10 per cent) and by investing in more efficient information systems. The administration costs of supporting new initiatives in the fields of education and training, public undertstanding of science and industrial liaison have been contained within these reducing levels of resource provision. Drawing on raw data compiled for the 1995 Forward Look of Government-funded Science Engineering and Technology, the National Audit Office have commented, in a draft discussion document on PPARC's Performance Indicators, that PPARC ranked first amongst the Research Councils for administrative expenditure and the proportion of gross spend and for gross spend per headquarters staff member. The National Audit Office pointed out the need for care in interpretation, given that Research Councils are very different. They commented that much of PPARC's expenditure goes on large sums to international facilities. While this still needs administration—in the way a private company might manage its foreign investments—such expenditure might be less costly in terms of each poind spent than managing some other activities. The NATO recognised, nonetheless, that such measures can provide relevant benchmarks. The figures are as follow:

Administrative expenditure: PPARC

	1994–95 *£ million*	*1995–96* *£ million*
(A) Central Administration	5.4	5.0
(B) Total Expenditure	184.9	200.3
A as a percentage of B	2.9%	2.5%

Source: Business Plan 1995

Comparison of Research Councils (1994–95)

	PPARC	*BBSRC*	*NERC*	*EPSRC*	*MRC*	*ESRC*
Administrative expenditure as a proportion of gross spend	2.9%	4.5%	4.5%	4.6%	6.3%	6.4%
Gross spend per headquarters staff member	£1,778K	£912k	£1,074k	£1,114k	£896k	£581k

Sources: 1995 Forward Look of Government-funded Science Engineering and Technology

Key:	
BBSRC	Biotechnology and Biological Science Research Council
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
MRC	Medical Research Council
NERC	Natural Environment Research Council.

8.13 The future roles of the Royal Observatories' UK bases and the two island sites (Hawaii and La Palma) are currently the subject of a Prior Options Review commissioned by the President of the Board of Trade and submitted to Ministers at the end of 1995. Council is preparing to discuss the practicalities and timescale of implementation arrangements at its February meeting.

8.14 Council's current plans for reduction in the Royal Observatories will result in further savings.

THE RESEARCH COUNCIL'S RELATIONSHIP WITH THE OFFICE OF SCIENCE AND TECHNOLOGY (OST)

8.15 PPARC recognises that the 1993 White Paper imposed a structural duality on the role of OST. On the one hand the White Paper set up six independent Research Councils, each with a Royal Charter, their own part-time chairman, usually a distinguished senior industrialist, and (for EPSRC, ESRC, NERC and PPARC) a Chief Executive newly recruited from senior levels in the academic world. At the same time, the White Paper announced the abolition of the former, consultative, broadly based body the Advisory Board for the Research Councils (ABRC), and its replacement by the single post of Director General of Research Councils (DGRC).

8.16 The Government's intention, stated in paragraph 3.24 of the White Paper, was "to give more central co-ordination and strategic direction to the Council's activities". To support the then Minister (the Chancellor of the Duchy of Lancaster) in this, the post of DGRC was given a series of tasks set out in paragraphs 3.26 to 3.27 of the White Paper.

8.17 A degree of tension was therefore inevitable between, on the one hand, the newly formed Research Councils, apparently independent to develop their own character and strategy; and on the other hand, the post of the DGRC, charged with developing more central co-ordination and strategic direction. An example of the tension was the desire of the PPARC to develop an independent policy for postgraduate training, which conflicted with the OST's wish to develop a more closely coordinated approach to such training.

8.18 In the practice, on a day to day basis, issues are resolved in regular discussion between the Chief Executives and his fellow Chief Executives, and with the DGRC.

8.19 PPARC is concerned at the number and range of new initiatives promoted by OST—the Government Forward Look; Technology Foresight, the Public Sector Research Establishment (PSRE) Scrutiny, the ROPAs Scheme; the Senior Management Review; the Cross Council Efficiency Review. Against a background of reducing headquarters staff these initiatives require staff and senior management time and effort.

Figure 1

Division of Programme Funding in 1995/96

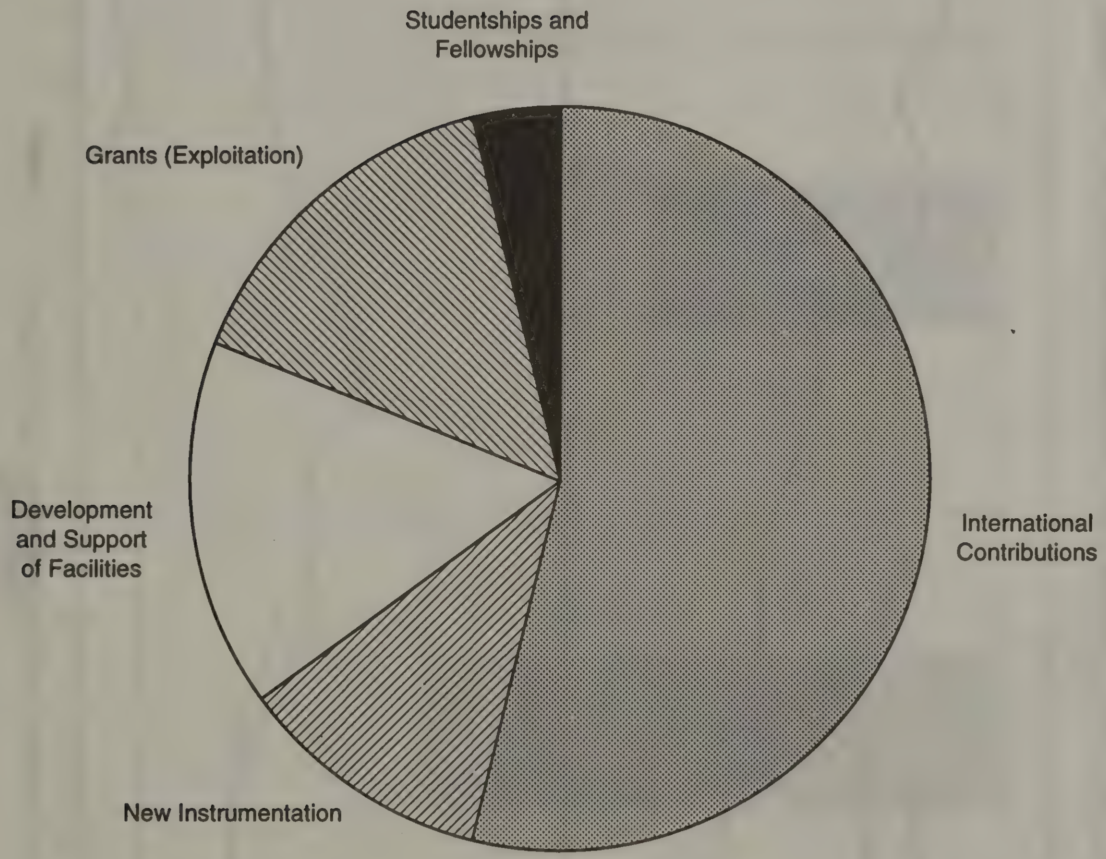
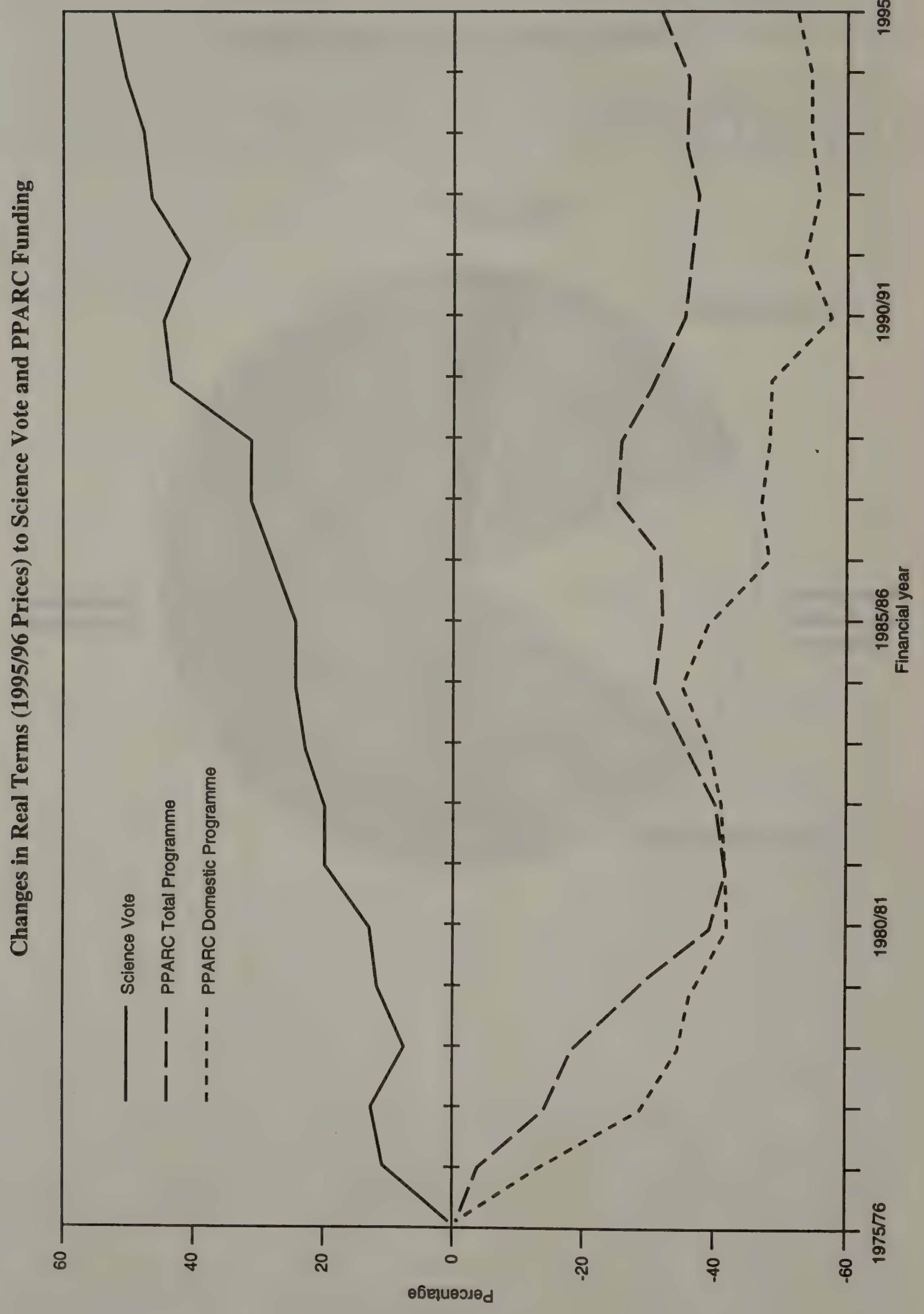


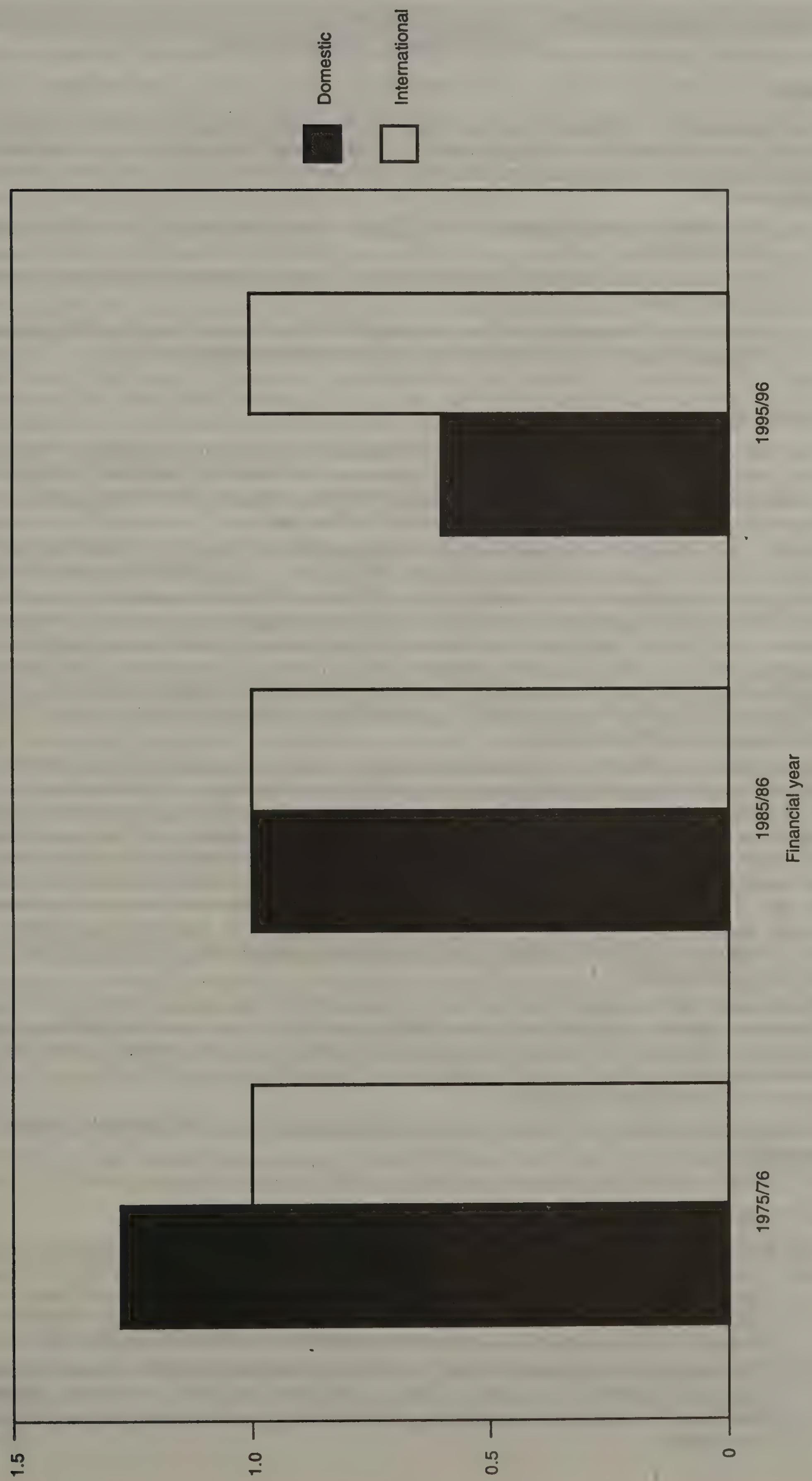
Figure 2


Changes in Real Terms (1995/96 Prices) to Science Vote and PPARC Funding

1 May 1996] *[Continued*

Figure 3

Ratio of Domestic : International Research Funding



Further memorandum submitted by the Particle Physics and Astronomy Research Council (10.4.96)

THE DEVELOPMENT OF THE 1996 BUSINESS PLAN, AND ADDITIONAL INFORMATION ON THE PPARC COMMUNITIES

SUMMARY

This Supplementary Memorandum summarises the new policy direction underlying the 1996 PPARC Business Plan, which has been developed since the PPARC main Memorandum was written (putting a cap on total funding for particle physics including the CERN subscription); and in an Annex presents recently complied data on:

- the academic community supported by PPARC (about 40 per cent of the total for physics, and in good health);
- the factors influencing the choice of physics at undergraduate level (dominant importance of PPARC Subjects);
- international comparisons of the standing of UK astronomy and the UK particle physics community (both very cost-effective and highly regarded internationally).

INTRODUCTION

In the Memorandum already submitted to the Committee, we stated (in paragraph 8.1) that, in response to the Committee's request, a Supplementary Memorandum would be submitted setting out how the Council's 1996 Business Plan would differ from the 1995 Plan, when the PES allocations were known, and the Council had had the opportunity to discuss their implications.

PPARC was advised of its allocation from the Science Budget in January. This provided a total of £191.68M in 1996–97, with planning figures of £191.73M in 1997–98 and £194.90M in 1998–99; to which was added a further £15.04M in 1996–97 and £18.0M in 1997–98 and 1998–99 to cover the increased sterling cost of the CERN and ESA subscriptions due to unfavourable exchange rate movements. At the time the Chief Executive, Ken Pounds, made public his welcome for the continuing help in covering the exchange rate increases in the CERN and ESA, which together with the efficiency gains agreed by ESA Ministers should enable the Council to put some money back into the domestic space science programmes. In the case of CERN and particle physics he warned that the projected subscription increase was so large as to threaten the whole balance of the UK programme.

At its meeting on 27–28 February, the Council discussed the broad direction for its 1996 Business Plan, based on detailed written submissions and oral presentations from its two science advisory committees—particle physics and astronomy. The committees had formulated forward research programmes using realistic assumptions about the capacities of their respective scientific communities and the range of international opportunities available, which exceeded by some 25 per cent the actual allocation projected for PPARC—even though funding them would represent no more than a return to the equivalent investment levels 10 years or so ago. The Council also had available the data attached as Annex to the present document on the academic communities supported by PPARC; the factors influencing undergraduates' choice of physics (strong dominance of PPARC subjects); and international comparisons of the UK particle physics and astronomy communities.

The Council took account of detailed earlier reviews of both the particle physics and the astronomy programmes; and its strategic direction determined last summer. On that occasion it had determined to give high priority to its education and training programmes; the promotion of industrial benefits, and the public understanding of science; and to aim for a balance in its research programme of not more than 50 per cent committed to international subscriptions.

Drawing on these inputs, the Council agreed that the following broad principles should underpin its 1996 Business Plan.

THE 1996 BUSINESS PLAN: BROAD PRINCIPLES

(i) Measured by objective indicators proposed by NAO, both UK particle physics and astronomy researchers remain world class, and are sought-after collaborators; and by the same indicators are demonstrably more cost-effective than their key European partners. (French, German and Italian domestic programmes are two to four times larger than the UK's, but produce similar output—see Annex). The Government should therefore support them as areas of outstanding UK excellence.

(ii) The high level of scientific output today, in both programmes is the result of investments made 10–15 years ago. The level of investment has fallen progressively since then, to an increasingly dangerously low level. Failure to make equivalent investments now would jeopardise the output for future generations.

(iii) We are in a period of remarkable opportunities in astronomy both ground-based (in the run-up to Gemini) and space-based (with the new ESA Horizon 2000 plus just agreed); and in particle physics with the growing prospect of truly global collaboration based on the LHC at CERN, involving the USA, Japan and Russia, following the collapse of the US Superconducting Super Collider project.

(iv) These opportunities can be taken only in major international collaborations (mainly CERN and ESA). The Government's membership of these organisations effectively provides only the research infrastructure and thus makes economic sense only if the formal, mandatory, subscription (based on relative GDP) is backed up by support of a domestic programme capable of exploiting the infrastructure thus provided. (As noted above, the French, German and Italian domestic programmes are some two to four times larger than the UK's.)

(v) Because of the falling value of the pound sterling against the Swiss franc, the cost to the UK Science Budget of the subscripton to CERN has gone up by 27 per cent in the past three years. Given the present limits on that budget, this rate of increase is unsustainable.

(vi) Hitherto PPARC has been able to fulfil its mission to sustain excellence, by supporting research across a wide range of frontiers in science. While each area has been underfunded by international standards, and in relation to the UK community's size, quality and expertise, neither the committees nor Council have sought to impose an *a priori* absolute prioritisation by subject area. The Council recognises the committees' preference for this approach within each of their areas. But it sees also the danger of a generalised loss of competitiveness in continuing with such an undifferentiated approach. Accordingly it has now decided that it must differentiate in its approach between the two broad scientific areas within its remit.

(vii) Recognising the benefits of the Council's programme in education and training, the benefits to industry of the advanced technolgy it develops, and the success of PPARC subjects in public understanding of science and attracting young people into science, the Council will fund these programmes as a priority.

(viii) In astronomy the Council will reverse recent and planned cuts, in order to take advantage of a number of exciting science opportunities and new projects that have been awaiting decision. The planning total for astronomy (including the ESA subscription) is £94.2M in 1998/99.

(ix) In particle physics the Council re-affirms the need to support a domestic programme at or near the present level as the minimum required to make UK membership cost effective, although it notes that this does not provide for the UK to meet its "fair shares" obligations to the LHC detectors. But in order to achieve even this will require PPARC to reduce its commitment to the UK subscriptions to CERN. By imposing a ceiling on its total spend on particle physics to the current level of £95.5M, it will seek to limit its contribution to CERN to no more than £66.5M per annum. PPARC is currently entering into discussion with the Government about how to achieve this, noting that negotiations will be needed also with other CERN members states' governments. In these discussions, the Council will draw attention to the minimum level of domestic programme required to validate the Government's membership—below which, the value of that membership would inevitably be drawn into question.

Although Council has sought to improve the resources available for new investment in astronomy in developing the 1996 Business Plan, it remains concerned that the provision remains low by past UK and present international standards. Investment in new instrumentation or projects, and in ESA space missions, remains substantially below the cost-effective optimum, and there is no provision for the replacement of already obsolescent facilities. Investment levels in the LHC detectors are entirely dependent on success in securing additional resources or a reduction in the UK CERN contribution.

The 1996 Business Plan document

The PPARC executive is currently drawing up a detailed Business Plan document on these principles for submission to OST. When complete, and given OST's approval, this document will be made available to the Committee.

Annex

The attached annex summarises the findings of recent surveys and statistics not available at the time of writing the main PPARC Memorandum, concerning:

(a) the academic community supported by PPARC; (about 40 per cent the total for physics, in good health)

(b) factors influencing the choice of physics at undergraduate level; (dominant importance of PPARC subjects)

(c) international comparisons of the standing of UK astronomy and the UK particle physics community; (the UK very cost-effective and highly regarded).

Annex

Annex to Supplementary Memorandum by PPARC

SUMMARY

This Annex summarises the findings of recent surveys and statistics not available at the time of writing the main PPARC Memorandum, concerning:

(a) the academic community supported by PPARC; (about 40 per cent the total for physics, in good health)

(b) factors influencing the choice of physics at undergraduate level; (dominant importance of PPARC subjects)

(c) international comparisons of the standing of UK astronomy and the UK particle physics community. (the UK very cost effective and highly regarded)

(a) *The academic community supported by PPARC*

1. Table 1 attached gives a statistical overview of the number of institutions, tenured staff, research assistants (RAs), Fellows and PhD students directly and in directly supported by PPARC. Table 2 (taken from PPARC Annual Report Appendix 2) shows the distribution of PPARC support between institutions.

2. Several points are worth noting:

— the community represents about 40 per cent of the total for all physics;

— it is divided very roughly 3:2 astronomy: particle physics;

— some level of support reaches a total of nearly forty different institutions;

— but the bulk (about 80 per cent) is concentrated in the top 10 universities. Six physics departments in those universities were marked Grade 5 in the most recent Higher Education Funding Council Research Assessment Exercise and four were marked at Grade 4.

3. It is PPARC policy, particlarly in astronomy, that while resources are concentrated in a relatively few keys centres—for obvious cost-effective reasons—support is also available on a competitive basis to small groups, even individual workers in any university. The individual or small group in astronomy can still make valuable contributions to research, not only in theory. PPARC is committed to accepting valid research grant applications from any university capable of supporting them.

RECENT GROWTH IN THE COMMUNITY: NEW ACADEMIC APPOINTMENTS

4. A recent survey of university physics departments has revealed that a total of 11 new Professors and 53 Readers, Senior Lecturers and Lecturers have been appointed in the UK over the last four years in astronomy; and 3 Professors and 34 Readers, Senior Lecturers and Lecturers appointed in particle physics.

5. These figures argue both for the present health and likely future vitality and UK role in these subjects, but also universities' recognition that astronomy, in particular, is a significant factor in influencing undergraduate choice of courses and hence an aid to recruitment (see also below). With a total of some 560 academic posts and an average of 35 years tenure, an average rate of recruitment would be 16 appointment per year. The higher recent average of 25 per year shows the real growth in the community. Moreover, because recruitments are being made from different age bands, the age distribution is becoming healthier and a generation of new research leaders is being put in place.

6. There is also evidence that those physics departments which have (introduced) an astronomy option/module have suffered less than others, if at all, from the general decline in physics student intake.

(b) *Factors influencing the choice of physics at undergraduate level*

7. A survey conducted for the Institute of Physics in 1984 revealed the large extent to which topics in the PPARC area influenced school leavers' choice of physics for undergraduate study. PPARC repeated the same survey, with some updating, in November 1995. The results show that the influence of PPARC topics has slightly increased over the period. In 1995 65 per cent of students cited "Relativity and Gravitation" as influencing their choice (55 per cent in 1984), and 55 per cent cited Astronomy, astrophysics, cosmology and

space research (40 per cent in 1984). The other favourite topics were Quantum Theory (cited by 43 per cent) and Elementary Particles (34 per cent). Rather surprisingly, more applied aspects such as Electronics (14 per cent), (Optics 12 per cent), Nucleus and nuclear energy (16 per cent) scored significantly lower, and showed a decline in appeal since 1984. Table 3 shows the scores for each topic. (Full copies of the reports are available.)

8. Other findings to emerge were:

— a marked preference for the new MPhys/MSci courses amongst students with an interest in PPARC topics;

— a decline in the influence of school text books in affecting choice, coupled with an increase in influence of popular science books and journals—a finding which should interest both school teachers, publishers and PPARC.

9. Overall these findings confirm and reinforce PPARC's view that the subjects which it supports are a major factor in influencing young people's choice of physics at university. PPARC intends to follow-up this study with a similar study on factors influencing the choice of physics A-level at school. This should quantify our belief that the same positive influence of PPARC science is found at schools level, with consequent benefits for a much wider area of training, including subsequent undergraduate course recruitment in eg engineering.

(c) *International comparisons of the standing of UK astronomy and the UK particle physics community*

10. Two recent surveys have confirmed the high international standing of the UK scientific communities in astronomy and in particle physics. Because of the very different ways in which research is undertaken and reported in particle physics and in astronomy the surveys cannot easily be compared one with the other.

(i) *Bibliometric analysis of the relative standing of UK astronomy 1981-1993*

11. The results show that not only has UK astronomy increased in world standing as measured by publication analysis, it has also increased in comparison to other research areas in the UK.

12. Research results in astronomy are still predominantly reported in specialist, refereed journals. A measure of a research paper's impact is the number of time which subsequent authors cite that paper. Publication and citation analyses are now accepted as broad indicators of the perceived standing of different countries or large groups. The National Audit Office (NAO) recent Discussion Paper "PPARC: Performance Measurement" (December 1995) proposes 'bibliometric analysis—publication counts or citation rates' as a corporate performance indicator for astronomy research (para 2.19).

13. A recent PPARC study has used both the number of papers and number of citations to compare the UK's performance in astronomy with that of other countries and the UK's international standing in astronomy with its international standing in other field. The details and a complete set of analyses are given in the full report (available on request). The main conclusions are summarised below and in the four graphs attached (Figures (i)-(iv)).

14. In terms of its share of the world astronomy literature over the period, the UK ranked second to the USA and, apart from a dip in the mid-1980s, has been maintaining that position (Figure (i)). The average number of citations per UK paper increased over the period and by 1993 the UK was also in second place to the USA by this performance measure, having recently moved ahead of the Netherlands (Figure (ii)).

15. The UK's international standing in astronomy, as measured by publication share, was apart from the mid-1980's higher than that for other scientific fields (grouped together according to UK Research Council areas, see Figure (iii)). Measured by citations/paper (relative to the world average), the UK's international standing in astronomy was by 1993 ranking second behind the average for MRC sciences (Figure (iv)); having begun the period lower than the averages for all other Research Council areas. (Note that the database used includes particle physics within physics and that physics has been included in the EPSRC figures, although the effect is likely to be small).

16. These results seem to show that UK astronomy has been able to increase its relative standing both nationally and internationally, despite the fact that is share of the UK Science Budget has been declining. This would imply a reflection both on the scientific exellence of the community and a comment on its cost-effectiveness.

(ii) *Statistics on UK standing in experimental particle physics*

17. The scale of modern particle physics research is such that the role of an individual in an experiment, and the published results is much more difficult to assess. The NAO paper on performance indicators (above) notes, in paragraph 2.22, that: "Experimental particle physics presents particular problems. First, experiments are carried out by international collaborative teams involving hundreds, even thousands, of

scientists. All those working on an experiment tend to be listed, often in alphabetical order, as authors in publications regardless of the actual level of input; hence unsophisticated bibliometric techniques are of little use. And secondly, publication rates vary throughout the cycle of experiments. For example, construction for an experiment can take 10 years, when there may be relatively few publications."

18. NAO recommend UK contributions to international conferences or UK representation on CERN scientific committees as possible performance indicators for particle physics.

19. Statistics recently collected by PPARC and summarised in Table 4 reveal that France and Germany spend more than three times and Italy four times as much as UK on domestic experimental particle physics (despite Italy having a lower GDP). In Italy and Germany, manpower in domestic PP is over twice that of UK; in France one and half times.

20. Despite that advantage, Table 4 bottom line shows that UK scientists are on average represented at over twice their "pro-rata" level in CERN experiments for both LEP and LHC. The more detailed figures show that for the Delphi (LEP) experiment, for example, UK scientists are on 21 per cent of the relevant committees and teams, although the UK is contributing only 8.5 per cent of the funding—a ratio of 2.49. For the LHC CMS experiment the comparable figures are 7.4 per cent representations against 2.9 per cent funding. On the three key CERN committees, UK scientists represent over 18 per cent of the membership, against a funding contribution of about 14 per cent.

21. At the major international (Rochester) particle physics conferences, the UK naturally falls some way behind the USA in terms of convenors and plenary papers (usually fielding just under a quarter of the US total), but over the period since 1992 has consistently fielded more than France (ratio 1.62) Germany (1.17) and Italy (2.1).

22. Even allowing for the advantage which the English language gives UK scientists, the conclusion is that the UK community is achieving well beyond the pro-rata share of involvement and international recognition that would be expected from the funding provided.

23. Full details of the statistics are available.

Table 1

THE PPARC RESEARCH COMMUNITY

UNIVERSITIES	*Number of Institutions*	*Tenured Research*	*RA*	*Fellows*	*Students (PhD)*
Astronomy and Astrophysics	33	232	186	not possible to desegregate	
Solar Terrestrial Physics	21	46	91		
Planetary Science	21	53	61		
Total	**38**	**331**	**338**	**39**	**278**
Theory (included in above)	29	170	112	—	—
Particle Physics	17	147	162	17	131
Experimental Particle Physics Theory	12	84	24	22	48
Total	**18**	**231**	**186**	**39**	**179**
Total PPARC supported	—	**562**	—	—	—
Total all physics	**51**	**1,175**	—	—	—
CCLRC					
Astronomy	—	10	0	—	—
Particle Physics	—	22	15	—	—
Royal Observatories	—	7	5	—	—

NEW ACADEMIC APPOINTMENTS OVER PAST FOUR YEARS (Mid 1992 — Mid 1996)

	Professors	*Readers, Senior Lecturers & Lecturers*
Astronomy & Planetary Science	11	52
Particle Physics	3	34

Table 2

APPENDIX 2—STATISTICAL INFORMATION

Table 1: Distribution of PPARC support to universities (research grants, studentships and fellowships) at at 31 March 1995

The list is ordered by grant expenditure in £ thousands
All data as at 31 March 1995

Expenditure in 1994–95	*Research Grant*			*Current Studentships*				*Current Fellowships*				*Main Areas Research Grant Activity*
Institution	*Particle Physics*	*Astronomy and Space*	*Total*	*Research*	*"Case"*	*Advanced Course*	*Total*	*Postdoc*	*Advanced*	*Senior*	*Total*	*(see below for key)*
UCL	761	4,440	5,201	20	4	3	27					B, C, D, E, I, J
Manchester	1,080	2,958	4,038	25	1	5	31		2		2	A, C, D, E, F, G, I, J
ICSTM	1,383	2,122	3,505	34	5		39	1	2		3	B, C, D, E, F, G, H, I, J
Leicester		3,399	3,399	15	5		20		1		1	B, C, D, E, F, G
Oxford	1,880	1,252	3,132	36	3		39	2	5	2	9	B, C, D, E, F, G, H, I, J
Cambridge	578	2,401	2,979	50			50	3	10	1	14	B, D, E, F, G, I, J
QMWC	742	1,180	1,922	26		2	28		3		3	B, C, D, E, F, G, I, J
Birmingham	653	1,012	1,665	17	3		20	1	1		2	B, D, E, F, G, I, J
Durham	177	1,297	1,474	24			24		2	1	3	B, C, D, E, F, G, J
Liverpool	1,166		1,166	11	1		12	3	3	1	7	I, J
Glasgow	476	535	1,011	16	3		19		3		3	B, C, D, F, G, I, J
Sheffield	183	530	713	8	2		10					B, F, G, H, I, J
Sussex	185	519	704	13		5	18	2	2	1	5	B, C, D, F, G, J
Kent		593	593	5	1		6					C, E
Edinburgh	282	139	421	19			19	2			2	E, F, G, I, J
Southampton	112	300	412	12	4		16		3	1	4	B, D, F, G, J
Lancaster	282	129	411	5			5					B, F, G, I, J
Open	6	308	314	4	1		5					C, J
St. Andrews		299	299	9			9	2	1	1	4	B, D, E
Bristol	208	56	264	7			7		1		1	E, I, J
Royal Holloway	218	20	238	2			2					G, I, J
Queens University Belfast		233	233	1			1					B, D, E, F, G
Cardiff		230	230	8	1		9					D, F, G
Brunel	187		187	2	1		3					I, J
Aberstwyth		155	155	5	1		6					B
Umist		141	141	1			1					B, E
Hertfordshire		132	132	2			2					D, F, G
York		125	125	2			2					B
Newcastle		121	121	3			3					C, E

Table 2—*continued*

APPENDIX 2—STATISTICAL INFORMATION

Expenditure in 1994–95	*Research Grant*			*Current Studentships*				*Current Fellowships*				*Main Areas Research Grant Activity*
Institution	*Particle Physics*	*Astronomy and Space*	*Total*	*Research*	*"Case"*	*Advanced Course*	*Total*	*Postdoc*	*Advanced*	*Senior*	*Total*	*(see below for key)*
Liverpool John Moores		115	115	2			2		1		1	C, D
Leeds		110	110	7			7					F, G
Armagh Observatory		78	78	1			1					D
Keele		61	61	2			2		2		2	D
Swansea	60		60	5			5		3		3	G, J
King's College	39		39	2			2		1		1	G, J
Exeter		27	27									C
Nottingham		25	25					1			1	E
Lancashire		24	24	3			3					E, G
Aston			0		1		1					
Total	**10,658**	**25,066**	**35,724**	**404**	**37**	**15**	**455**	**17**	**46**	**8**	**71**	

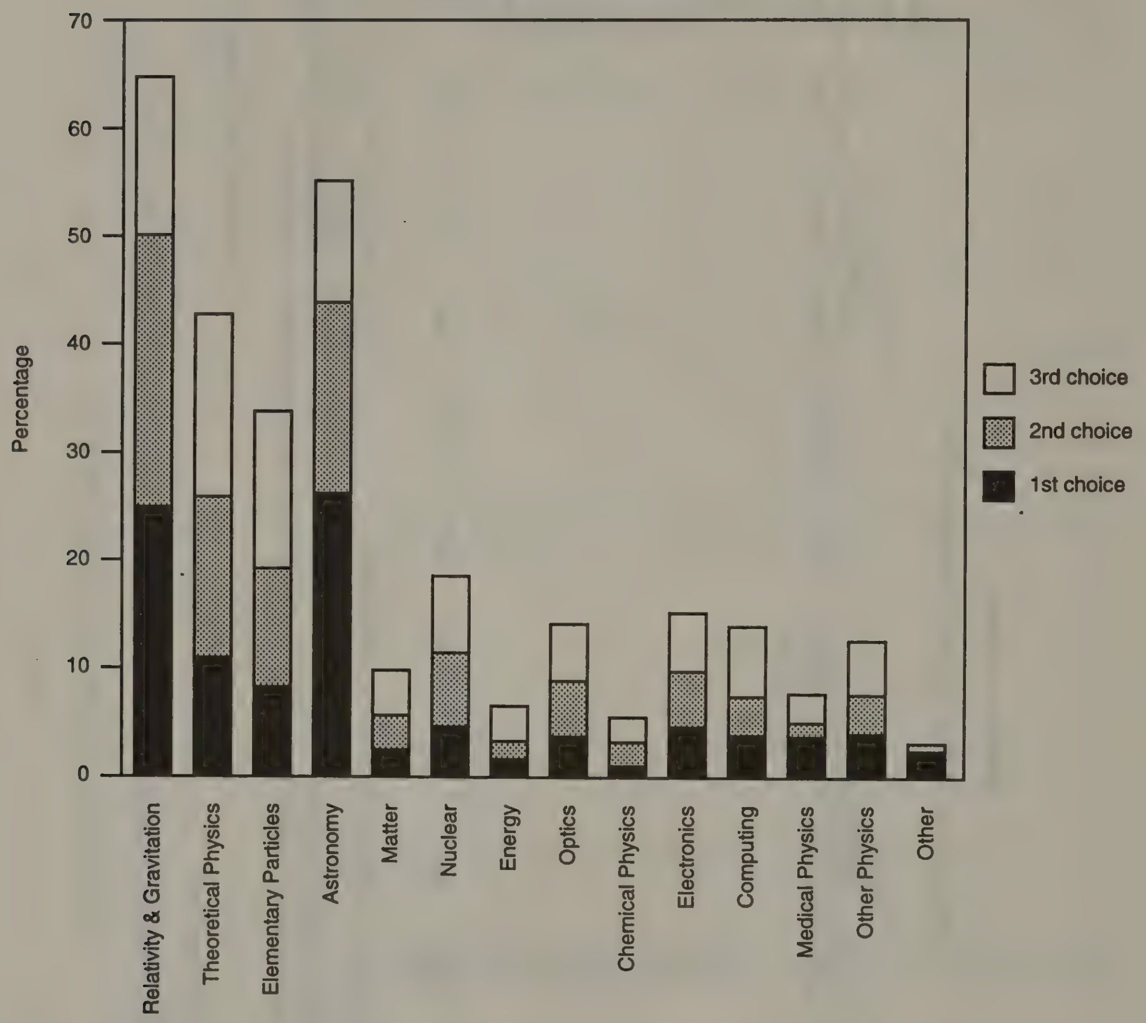
Key for areas of research grant activity:

A — astronometry, celestial mechanics, databases and survey astronomy
B — solar and solar-terrestrial physics
C — planetary science
D — stars
E — galactic and inter-stellar astronomy
F — extra-galactic astonomy and cosmology
G — physics and physical processes not specifically astronomy, planetary science or particle physics
H — dark matter
I — the origin of mass
J — the three generations and weak symmetrics

Percentage of students with first class degree (as at 1 October 1994) .... 59 per cent
Completion rate performance (as at 1 October 1994) .... 78 per cent

Table 3

Topics that influenced the choice of physics 1995 survey



Figures (i) and (ii)

Percentage of world astronomy papers produced by the 9 leading countries

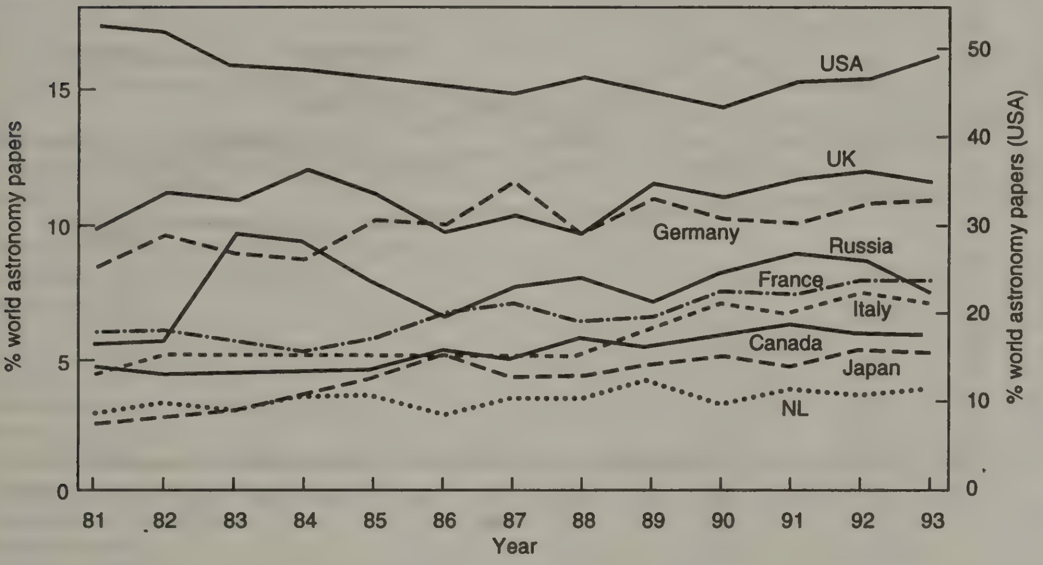


Figure (i) Percentage of the world's astronomy papers with at least one author from each of the nine most prolific countries. Note that the USA is on a separate scale.

Citation impact (number of citations/paper) in rolling 5-year windows, 1981–1993

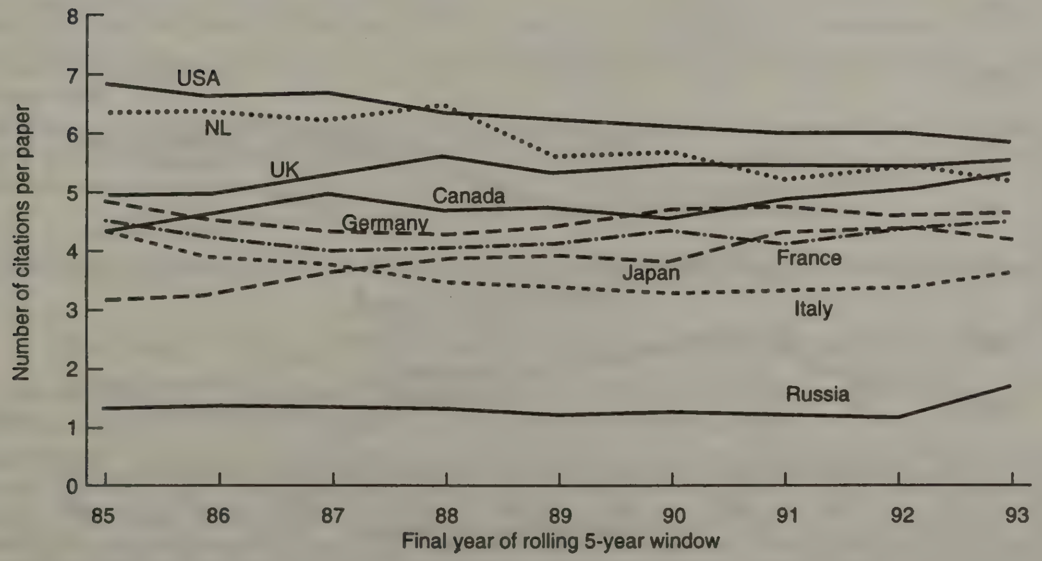


Figure (ii) Number of citations/paper for the nine leading countries in rolling five-year overlapping periods starting in 1981.

Figures (iii) and (iv)

Percentage UK contribution to world literature for astronomy and other research council areas

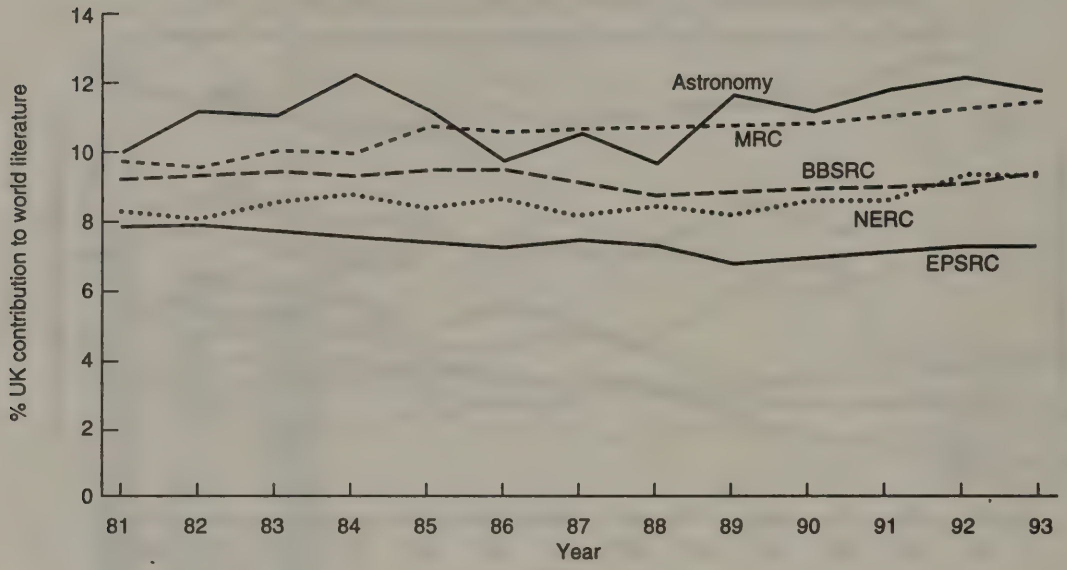


Figure (iii) UK astronomy papers as a percentage of the world astronomy literature compared with the overall percentage UK contribution to the world literature for fields falling within other research council areas.

Relative citation index for UK astronomy and other research council areas

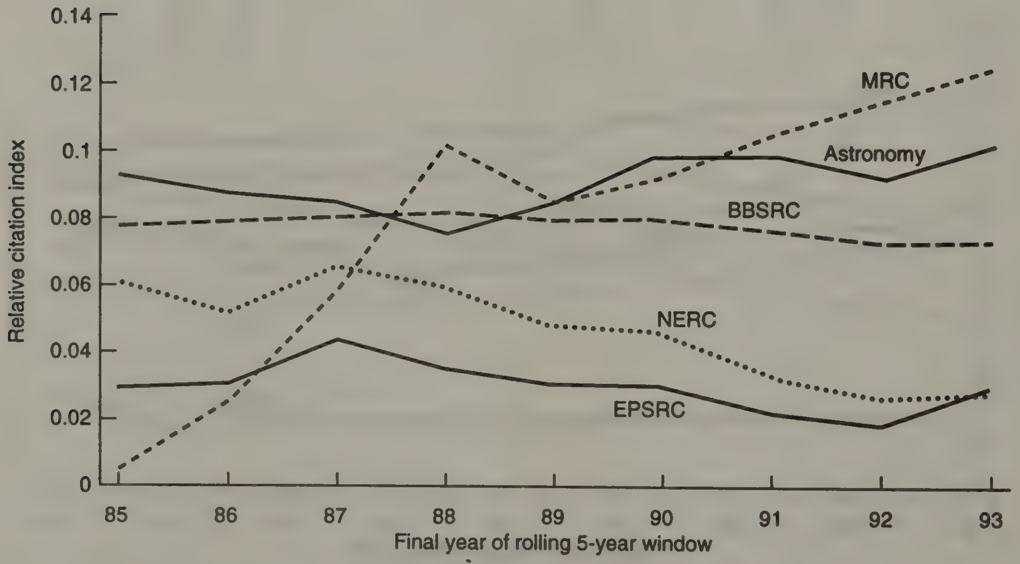


Figure (iv) Relative citation index for UK astronomy and average relative citation indices for fields falling within other research council areas, in overlapping five-year periods. The relative citation index is the log of the ratio of citations/UK paper to citations/all papers.

Table 4

COMPARISONS OF UK, FRENCH, ITALIAN AND GERMAN DOMESTIC EXPERIMENTAL PARTICLE PHYSICS PROGRAMMES AND RELATIVE OUTPUT INDICATORS

	UK	*France*	*Italy*	*Germany*
Population × 10^6	58	57	57	81
Normalised to UK	1	1	1	1.4
N.N.I. (Normalised to UK) (= CERN Subscription but Germany at 26.1%)	1	1.28	0.93	1.96
(1) Expenditure on domestic experimental programme (£M)	25.8	82.5	115.3	81.9
Normalised to UK	1	3.2	4.5	3.2
(1) Experimental permanent PhD Manpower (including University academics)	247	417	705	592
Normalised to UK	1	1.7	2.9	2.4
Expenditure/Permanent PhD (£K)	104	198	164	138
(1) Total manpower (inc. PhD students)	786	1,284	2,067	1,687
Normalised to UK	1	1.6	2.6	2.1
(2) Speakers and convenors at four recent international conferences	21	13	10	18
Normalised to UK	1	0.6	0.5	0.9
Normalised to domestic expenditure (UK = 1)	1	0.2	0.1	0.3
Positions of Responsibility on CERN Peer Review Committees (LEPC, SPSLC, LHCC)	8	8	6	9
Normalised to NNI (CERN contrib) (UK = 1)	1.0	.78	.70	.57

	LEP	*HERA*	*LHC*
UK positions of responsibility on experiments (No. of UK people)/(Total positions)	36.1%	23.9%	7.4%
Normalised to funding of experiment (UK/Total)	2.2	1.9	2.2

(1) Excludes operation of HERA and associated infrastructure of DESY and salaries of University academic staff.

(2) These are plenary speakers and parallel session convenors at four of the most recent major international particle physics conferences (three Rochester + one Europhysics). In comparison, the total number of US speakers in these conferences was 85.

Memorandum submitted by Dr Peter Williams, Chairman of the Particle Physics and Astronomy Research Council (30.4.96)

HIGH ENERGY PHYSICS: INDUSTRIAL, MEDICAL AND RESEARCH SPIN-OFF

A personal note to the House of Commons Select Committee on Science and Technology by Peter Williams, Chairman of the Particle Physics and Astronomy Research Council.

The PPARC's programmes are driven by a fundamental curiosity regarding the origins of matter and our universe. Astronomy and Space Science are typically observational in nature, but high energy physics seeks to devise experiments which can test the theories regarding matter, its origins and its constituents. These experiments often take engineering and material science to the very limits of what is possible and in so doing, provide a test bed for technologies of the future which find application in other areas of man's endeavours.

Since the establishment of the PPARC, we have taken upon ourselves as a primary obligation the requirement to seek out such applications for the broader benefit of science, industry, medicine and society. While this more focused strategy is in its infancy, it is nevertheless of interest to note the very large number of breakthroughs and technologies which have been facilitated first of all by developments in high energy physics in the years since the war. The list which follows is by no means exhaustive, but is intended to give members of the Select Committee a broader view of the spin-off benefits from past and future PPARC programmes.

1. ACCELERATORS:

The vast majority of experimental particle physics relies on the use of systems which accelerate charged particles such as electrons and protons (or their anti-matter equivalent) to high energies in order to produce either collisions between particle beams or in some cases deliberately to produce other particles such as neutrons or energetic radiation such as γ-rays.

All of accelerator technology is initially driven by the developments in experimental particle physics. "Yesterday's" fundamental research equipment can then of course be applied in "today's" technology in other areas.

(a) *Semiconductor Industry*

(i) Ion Implantation is one of the key stages in "doping" semiconductors during the processing of silicon or gallium arsenide to produce integrated circuits. Very many generic types of such semiconductor devices require ion implantation processing which uses a charged particle accelerator, usually a heavy ion "linac".

Industry size:	Semiconductors—greater than $100 billion pa Equipment—greater than $1 billion.
Prime supplier:	Varian Corp., USA. Applied Materials, USA.

BUT

Much of the technology development was done at Harwell in the 1960s and 1970s. It is UK industry's fault that British firms such as Lintot did not survive in the face of US competition.

(ii) X-ray lithography is a new processing technique currently being pioneered by IBM, Oxford Instruments, NTT, Sumitomo and numerous other Japanese companies. A compact electron synchrotron is used to provide the X-ray source which then prints sub-micron features on semiconductor wafers. Above 1 Gigabit in memory chips by the year 2000, X-ray lithography will almost certainly be required for at least part of the processing, opening up a potentially large new market ($100 million pa for equipment alone).

Oxford Instruments developed the Helios Company Synchrotron with the help of the Daresbury Laboratory and the SERC; Daresbury, remember, was initially established as a high energy physics research facility.

(b) *Medicine*

(i) Oncology: electron beam linear accelerators ("linacs") are widely used in cancer therapy, usually by producing a secondary X-ray or X-ray beam which impinges on the tumour.

(ii) Oncology: Proton and Neutron therapy. A different form of accelerator—the cyclotron—is in use in experimental trials in the UK, USA and Germany for both proton and neutron tumour irradiation.

(iii) Radiomedicine: many radiopharmaceuticals used in therapy and in diagnostic imaging are prepared by using a cyclotron to bombard a target to yield radioisotopes via nuclear transmutation. Imaging techniques such as "SPECT" and "PET" are rapidly entering fields such as cardiology and neurology as new diagnostic tools.

Industry size:	$1-10 billion per annum.
Principle suppliers:	UK, USA, Germany and Japan (eg Amersham (UK), Varian (USA), Oxford Instruments (UK), Siemens (Germany), Toshiba (Japan)).

(c) *Industrial Uses*

(i) Food Sterilisation: irradiation using an electron linac is being introduced in certain areas of food processing, eg in the preservation of freshness in fruit. At present it is a small market in total size but may grow if concerns regarding the long term safety of the procedures can be allayed.

(ii) Non Destructive Testing: a variety of accelerators is used in systems for radiography of welds on nuclear power stations or large steel structures and in the aerospace industry. Oxford Instruments and Rolls Royce are pioneering the application of cyclotrons to the neutron radiography of air frames and aero engines. At present all turbine blades on all aeroengines must be neutron radiographed at a reactor location. With a compact cyclotron, a "mobile" source of neutrons is provided which can be transported to a manufacturing or airframe testing environment. The USAF are currently engaged in trials and the Korean Government is showing signs of interest in civil aerospace applications.

(d) *Research Uses:*

The electron synchrotron was developed originally as a tool of high energy physics research. Today the electron storage ring is one of the prime tools of research in areas as diverse as protein crystallography, materials and composites, surfaces and catalysts, semiconductors, in vivo microscopy and many others.

In the area of biochemistry in particular, structural determinations via synchrotron radiation X-ray crystallography and via nuclear magnetic resonance are the fundamental and essential tools for all primary research into new molecules.

Without the "driver" of particle physics, synchrotrons would simply not exist as they do today, with over 80 systems world-wide. Note that above per (a) (ii), the application of X-ray lithography in the semiconductor industry also required the use of this technology.

2. SUPERCONDUCTIVITY:

For more than 50 years following the discovery of this phenomenon in 1911 by Kammerlingh Onnes, there were few scientific or industrial applications of this breakthrough. The discovery of the A15 alloys such as Nb_3Sn changed that and facilitated an "enabling technology". The first applications, however, were by high energy physicists in making magnets and other devices for accelerators. As ever, high energy physics produced the drive in the development of the technology.

Even more importantly, this pushed a requirement for usable engineering materials. Superconducting cables and wires suffer from a curious handicap of "AC" losses, but pioneering work at the Rutherford Laboratory by the high energy physicists produced multi-filamentary wires and cables which are today the bedrock of a diverse range of applications, many of which have a British presence.

(i) Magnetic Resonance Imaging or MRI: Without cheap, reliable multifilamentary conductors developed initially for high energy physics applications, there would simply not have been an MRI Scanner. Today, with superconductivity "tamed", there are over 8,000 world-wide, invented in Britain, developed in Britain and contrary to the errors perpetuated as ever by our press and media, with a significant, ongoing British presence today in the "dreaming spires" of Oxford.

Industry size:	$2 billion per annum.
UK content:	Oxford Magnet Technology—$130 million per annum. BTG (MRI license) approaching $50 million cumulative and growing.

(ii) NMR Spectroscopy: MRI grew out of NMR, a fundamental chemical research technique, which also uses high field superconducting magnets where the UK is again a world leader.

Industry size:	$250 million per annum.
UK content:	$30 million per annum, (Oxford Instruments).

(iii) Finally, the world's largest project in superconductivity will be the LHC Collider at CERN. This will again undoubtedly drive the technology hard (and is already doing so) with numerous spin-off benefits and opportunities. High temperature superconducting current leads made of the new materials discovered at IBM in 1986 will be used extensively. Again, Oxford Instruments will be heavily involved. The Collision Magnets and the associated detectors will push the technology even harder.

3. Software, Computers and Electronics:

A little known fact is that the World Wide Web, now the subject of intense industrial activity the world over, was developed by high energy physicists at CERN as a means of electronic communication. What are the industrial spin-off effects? Incalculable.

In addition, the requirements placed on ultra fast electronics, sensors, computers and parallel processors, and all forms of software again drive the technology forward. Just walk around the computer and communication centre at CERN and you will see the names of all the worlds major computer and telecommunications companies.

Future developments and new industries? We can only guess.

4. It is difficult to summarise the above except in terms of a huge outpouring over the years of enabling technology from particle physics. This has been captured by Industry, Healthcare and other researchers, to the benefit of a very broad community indeed. Can we calculate future benefits on some linear model relative to today's investment? I am afraid not, at least not with any rigour or conviction.

Can we calculate the future penalties of our non participation in what is undoubtedly an expensive science? Again, I believe the downside is also incalculable. Should we choose to be a spectator rather than a participant, however, it will be too late to rectify the situation when it does become apparent that damage has been done to one of the UK's prime scientific intellectual assets.

Examination of Witnesses

Dr Peter Williams, Chairman and Professor Ken Pounds, Chief Executive, PPARC, examined.

Chairman

173. Good afternoon, Dr Williams and Professor Pounds. Thank you very much for coming. It is for us of course a hugely important event. We are currently engaged in a review of PPARC in relation to our remit as the Science and Technology Committee which can take a view on each of the Research Councils where, of course, the Government is spending its money and where it is addressing scientific priorities through the way in which they have been re-fashioned and are re-presented. I think the first part of our discussion will be about money and all that, which is obviously a huge problem. The second will be what is being done with it. May I open then by saying do you think—and I expect a pretty short answer to this—that the proportion of the science budget spent on PPARC subjects is appropriate?

(*Dr Williams*) Before I ask my learned colleague, Chairman, to respond to that, you have figures before you in which you have seen the real terms growth of the science vote as a whole over the years and you have I think what is incontrovertible evidence that the budget for which we are responsible has regrettably gone in the opposite direction.

174. Well, the word 'appropriate' is used here?

(*Professor Pounds*) My response to that would be that we have a mission, we have certain challenges, certain opportunities and we need to measure the money we have in terms of the way in which we are able to respond to those opportunities and those challenges. Our basic concern, which has grown more acute over the last two years, is that we really do believe that we are suffering in our ability to deliver value for money, if you like, from an overall under-funding of our domestic programme. I know many other things get involved, the international/domestic balance, all of that, but the real bottom line, I think, in our ability to deliver good value for money is a level of under-funding that we believe we have a number for. We could discuss that in more detail later if you wish.

175. I think this does lead on to my second question which of course is in the memorandum to which Dr Williams has referred, to say that the plans presented for astronomy and particle physics exceeded the PPARC allocation by some 25 percent or thereabouts. Your memorandum speaks of a shortfall in total between £10 to £15 million per annum, so if we regard that as sort of your base problem, the question then is how much extra money do you feel is needed for a sensible programme for particle physics and how much for astronomy? Shall we have them separated?

(*Dr Williams*) I will ask Professor Pounds, if I may, to comment first on that one, but I would like to come back on that one, Chairman.

(*Professor Pounds*) What we tried to do in advance of our business meeting in February was to take a bottom up view of our programmes in order to try and quantify the shortfall in funding that would allow us to do a really good job with the opportunities in front of our particle physicists, astronomers and space scientists. Having gone through that exercise we came up with a number of the order of £20 million and it was interesting to note—and I think we mentioned that in our written evidence—that that difference between what is currently around £80 million, as the amount we can really spend on our domestic programme, the £100 million that this exercise told us we really needed to do a good job, represented simply the difference in real terms between the domestic funding we have now and that we had as recently as the mid-80s. So it is the decline, in our domestic spending power over that period that we now believe is causing us the real difficulty. Now you asked about trying to quantify that shortfall and said in the past we have quoted numbers like £10 million, £15 million a year. There is

[**Chairman** *Cont*]

another aspect to that however that we have not brought perhaps as clearly to your attention as we should and I would like to do that just briefly now. Looking ahead, one of our real challenges is to find a pulse of money that we need in order to properly fund the United Kingdom participation in the LHC programme. Over the next six or eight years, we have to find a total amount of money that considerably exceeds any reasonable expectation from our current plan and therefore aggravates our under-funding problem. One of the challenges we have is to try and find a way around that which really does need an injection over a finite period of time and there are various ways we have in mind how that could be addressed, but it obviously needs help from Government to do that.

(*Dr Williams*) If I may, Chairman, to give you an industrial analogy to the situation as I see it, your question is quite rightly directed at the current revenue problems which we have drawn to your attention. Underlying those existing problems today is a hidden assumption—although I think we have drawn it to your attention—which is that, in effect, the value which we can derive out of PPARC's programmes today under current funding regimes, relies on our utilisation of assets and past investments which were made previously and which have already, in effect, been paid for. If you like, the analogy would be with a company whose capital investment programmes, with all the tooling and equipment amortised years ago, was of course still contributing usefully to the revenue of the operation. As we go forward, therefore, we have two problems. We of course have to grapple with this revenue deficit issue by drawing it to your attention, but we have in addition to wrap our arms around the problem of how to adequately fund, if you will, the capital in future programmes. This is what Professor Pounds is referring to by way of a request that we put before you at some stage coherently today, a concept of a pulse of money, a one time sum, which I would term an exceptional capital sum during the life of the construction of the LHC Collider which will relieve pressure upon our current account, if you like, our revenue account and I think I would draw attention to that. I think it is a good analogy, I think it is very relevant to PPARC.

176. You do not have the facility, or do you, of going back to the shareholders for a one off payment on the accounts!

(*Dr Williams*) Rights issues are proving difficult, Chairman!

177. They are, are they? You will have to take further advice on the matter! But I was trying to press you on the separation of particle physics and astronomy in relation to what we might term the drought you have been discussing? Now how do you view the proportionate amount that you would seek to fulfil those two obligations?

(*Professor Pounds*) I think, Chairman, the main difference in the under-funding, looking forward five to eight years, between the two main parts of our programme—astronomy and space and particle physics—is due to the impact of LHC. So I think that in hand waving terms one could talk about an under-funding level on the general astronomy and space programme of maybe £5 million a year and similarly for particle physics. But one has to take into account in addition the lumpy nature of the investment required to make sense of the LHC.

Chairman: Well, that is an inheritance; a rich one I am told. Dr Williams?

Dr Williams

178. May I ask you, the gearing in particle physics between the CERN contributions and home-based particle physics? Just from memory, I should have looked them up, but it is of the order of £60 million to the CERN contribution and something more like £20 million in terms of home-based; 3:1 for the work overseas. Now on our visit to CERN we had figures again that I have just broadly plucked from memory for Germany, France, Italy and so on and we are way out of line there, are we not, in terms of the amount of home-based work? Is that not deeply unhealthy?

(*Dr Williams*) It is very worrying. In fact we drew your attention in one of the tables in one of the exhibits not just to the ratios which are themselves alarming, as you say, but the absolute sums of money involved in various programmes, particularly in Germany, France and Italy, in the domestic science programmes within those countries, compared to what we have domestically left over after we have paid our international subscriptions and that is a very serious problem indeed. It means, to use an oft quoted analogy, we have to be much better with our limited resources to achieve the level of scientific prowess which our European peers accord to us than they have to be with vastly richer budgets. They also have to pay their CERN contributions. France pays a very comparable contribution to the United Kingdom, but their domestic particle physicists have access to funds which are just vastly greater.

179. May I just follow up on that very briefly? What would be a healthier ratio; if it is now 3:1 CERN versus home-based, what would be a healthier ratio?

(*Professor Pounds*) I think the thing to concentrate on again is the required funding on the domestic programme. The actual numbers at the moment are more like 70 and 25 million. The 70 just buys membership of this club that at the moment we very much want to remain members of, but we want to remain active members. Therefore I think the really important question, having paid the membership fee, is having access to enough money to make sense of that. That, as I have said in, a steady state situation is a few million a year more than 25 million. However, looking ahead as we have done very carefully with our particle physics experts in the community recognising the opportunities that the United Kingdom have within LHC, would require the domestic funding to go through a peak lasting several years at maybe 35 million and therefore it is that pulse, which I have mentioned several times. That will not last forever and I think there is an interesting question—and I know Dr Bray has raised it—about what comes after LHC. How long does LHC actually serve the community? So to try and answer your question, I think that, as I say, the real challenge for us is how do we somehow or other lay our hands on—by borrowing, begging, stealing or what—the amount of money that would allow us to make sense

[Dr Williams *Cont*]
of our membership through the LHC intensive investment period and that rises to a peak, as I say, probably in volume about 35 million, so it is about £10 million more than we have now.

Chairman

180. On that analogy, you are talking about getting more out of CERN, is that right, as opposed to: "You have paid the membership fee. That is it, finished"? Are you talking about trying to get more out of CERN to spend on other things? Surely that is not the case? What you are talking about is the residual projects which you have in mind of particle physics, or astronomy? That is mainly what it is about?

(*Professor Pounds*) It is being able to be involved in the whole CERN programme, but LHC in particular, at a level, involving literally hundreds of scientists and technicians in the United Kingdom, that we can actually, win by the quality of our work. It is in that active participation that most people would argue that we actually get value for money.

181. But what is stopping you getting that involvement now?

(*Professor Pounds*) Because a substantial part of our £35 million actually goes in paying people, in paying scientists within the Universities and the CCL and also giving them the tools to do the work, to build the widgets to build the trigger circuits and so on and actually to make the trips to CERN and actively participate. The dominant part in this activity is actually just people.

Mr Thompson

182. I wanted to pick up something you have just been elaborating further on even though it refers to something that may come up again later and that is this question of the pulse of extra money for the LHC, which of course is CERN. There are two things that occurred to me which you may want to comment on. First, is it right to ask for a pulse of extra money for the international projects rather than for the domestic ones, because in my mind you seem to be implying: "Well, we would ask for a pulse for that, but we would not be looking for the same thing for anything domestically"? The second point I would make—and the question just came into my mind as you put this point—it seems to me that the argument I have heard from the scientific community is that we are, compared to other countries, under-funding scientific activity as a whole. If that is the case, it seems to me, if I may be blunt, a little weak to talk about a pulse, when what we should be arguing for is an overall increase. When I say 'we' I mean 'you'; the community should be asking for an overall increase rather than suggesting the LHC is something one off and then everything will go away and we will all live happily ever after. I am not sure if that entirely convinces me?

(*Professor Pounds*) In response to the Chairman's question right at the start, what I tried to say, Mr Thompson, was that there are two elements to our under-funding. There is this base line under-funding which, we have talked about in terms of £10 million a year, but on top of that, if you look at our actual requirement in the next six or eight years, due to the timing of the LHC project, that does put a pulse on top of that. The reason I think it is worth recognising as something different is the magnitude. The magnitude of our total domestic commitment to the LHC is, we believe, a minimum of £130 to £140 million over eight or ten years. That literally dwarfs everything else we do, even space projects. The most we have ever put into any of the big ESA space projects is of the order of £20 million. So it is the magnitude of this requirement that makes it different and that is why I believe that from the point of view of, as I say, the United Kingdom being able to get value for money out of its membership, we have to somehow try and find a way of handling this lumpiness. If I could just go on to add another point, Chairman, reading back in the papers that Sir David Phillips wrote before the White Paper, in pointing out some of the difficulties that various new Councils might actually meet, he did point to this special difficulty he anticipated PPARC might have. He used a phrase like "because of the lumpy nature of its domestic commitment" and I think what we are now looking at is this prediction of Sir David Phillips coming about. We are looking at a lumpy requirement that we should try and handle in some sensible way.

(*Dr Williams*) Could I just add another gloss? We would love to debate, and I hope we will be able to debate as part of these proceedings the general base line level of funding for these areas of science. I think that is a very fundamental issue that we have very strong, passionately held views about and I think it would be regrettable if we were not able to air those and discuss them today. But just by way of a clarification on this question of the lumpiness and the pulse of funding, perhaps we should clarify that if you will the CERN contribution pays for the operation of the laboratory and out of those funds collectively CERN management will build the Large Hadron Collider. The physics which is then carried out on the LHC requires what our colleagues behind us euphemistically refer to, to me, as experiments. These are actually large, hundreds of tons worth of extremely expensive and large high technology. These experiments and our involvement in these experiments have to be paid for out of the domestic line, so if you want to look at layers of the onion, at cores of our funding, we pay CERN first, we support the university groups, many of whom are represented here today, and the university scientists, aided and abetted by people in industry such as myself, then build the experiments to exploit the asset which is the LHC and the lumpiness is caused by, specifically in the case of the LHC, to very large experiments, to very large detectors and that is why they are of finite duration and finite cost.

Dr Jones

183. I just wanted to give you an opportunity to do what you said you wanted, which is to discuss your funding in more detail. You refer to other countries spending far more in this area of research, which is undoubtedly true, by then they spend less in other areas. If we go back to the Kendrew report which

[Dr Jones *Cont*]

recommends the 25 percent reduction,[1] that is what you are seeing, the £100 million down to £80 million, so why are you complaining? That was what was always planned for. That is the first point. Secondly, on this pulse of funding that you are talking about, could you explain; I presume you do not mean over just one financial year because that would be too narrow? You are talking about over the time that the experiments on the LHC are in full operation so that you have the maximum ability to take advantage of the facility?

(*Professor Pounds*) On the second point first on the sort of pulse that would be very useful. First let me say this is not unique to our problem with LHC; I think it is a problem that has to be addressed in the near future by Government in relation to several new large scale facilities for example the Synchrotron facility at Daresbury will eventually need replacing. Now I very much hope that this will be replaced with a machine in the United Kingdom as part of our contribution to world science, but that will require something like maybe £150 million and again there is a problem of how you fund that under the present arrangements. As for the LHC, the kind of pulse of new money I talked about—it may not be the best word—would top something like £60 million which we would need to have access to over a period of maybe six years. That is a figure that would be extremely difficult, in fact almost impossible to fit into our present level funding or in fact slightly less than level funding, without absolutely crucifying everything else we do, so I do not think it is easy to envisage how we could do that. Now the point again about the £80 million is basically one of being able adequately to meet the present opportunities. You are right in that it is a fact that in some of the other major nations in continental Europe they do spend quite a bit more on areas like particle physics, space science and so on. That is their choice. It is interesting to find, and I think we have objective evidence some of which we tried to share with you, that we actually do get better value for money. One reason might be that we have gone through this tough process of squeeze and natural selection, but there comes a point, I think, when that process can be taken too far and where you really cannot deliver on the investment that you have made and I think that is the point we are now trying to make *vis-a-vis* the LHC.

Dr Bray

184. Is not another way of tackling the lumpiness of the capital programme to re-phase the capital programme?

(*Dr Williams*) Yes, to some extent, Dr Bray. I think you are aware that some of that has already taken place. In the debate that took place between CERN on behalf of its Member States and the non-Member States, particularly America and Japan, the question of timetabling phasing has come up on many an occasion and it is a matter of record, if you go back to the very earliest proposals from CERN for a timetable on the LHC, that what is currently being proposed and what will be put before the final review meetings in 1997, is already a relaxation on the rate of investment and I think you would agree that there comes a point at which stretching things out in time, in expenditure terms, merely increases the size of the ultimate bill. Moreover, in the eyes of our scientific colleagues, it delays the onset of the time in which they can do useful scientific work with that investment. So I do not think we can simply say that we can always find £10 or £20 million by adding another one or two years to the programme or whatever the numbers may be. I do not think that beyond a certain point that is a valid argument and there has already been a degree of balancing between annual investment and cost.

185. Is not in fact what happened that the rephasing that CERN did offer is now being attempted to be clawed back by proposing to the Americans that their subscription be used to restore the original programme? The judgment as to whether that is the only terms on which the Americans would come in is the judgment of Professor Llewellyn Smith. I do not question his judgment of what the politics of science in America are, but that has to be set against the corresponding problems in the United Kingdom. If the Americans can cancel SSCC after they have spent already more than the total cost of the LHC, inevitably talk with the Americans has to be equally tough?

(*Professor Pounds*) May I comment on phasing? In a sense it would be more comfortable for us if the LHC programme was stretched out, but we have to recognise two things. The first is it is not entirely within our gift to decide that—we are only one of 19 Members—but the other point is that I think it is also well known that if you stretch out programmes in the end they cost you more. So that ideally what one should try to achieve in these high tech programmes is a kind of natural time scale, a time scale that does not require corners to be cut, does not require explosions of expenditure, but follows fairly naturally from the rate at which the community can actually do this very challenging job. With regard to phasing you could say that by having, with Government's help, access to a capital fund that we would then repay over a longer period of time is another way of phasing and I think it is actually a better way of phasing because it allows us to phase without, if you like, upsetting the whole international apple cart and adding costs.

186. I cannot see American and Japanese funding being used to provide the capital injection that you require?

(*Dr Williams*) Could I hazard an answer before I turn to Professor Pounds on that?

(*Professor Pounds*) Sorry, I think I did not actually make myself clear, so if I could just add to that. I am not expecting this capital fund to to be provided by the Japanese and the Americans. It has to be provided by the United Kingdom.

187. I am asking you why should it not be provided by the Japanese and Americans?

(*Professor Pounds*) Oh.

(*Dr Williams*) May I answer a slightly different but related question because, organised by the British Embassy, I have twice visited Monbusho on LHC

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[1] Footnote by witness: I should have clarified the Kendrew reduction, referred to by Dr Jones, was in relation to the CERN subscription, not the UK domestic spend.

[Dr Bray *Cont*]

business and indeed I have asked very similar questions to this at Vice-Ministerial level in the Ministry of Education as you well know. The answer has been unequivocal and very hard-nosed indeed, which is that Japan -and I would guess this also goes for America—does not wish to invest in the LHC programme in order to, as it were, lessen the burden on existing Member States. They wish to add value and quality to the programme and that has been, in essence, a pre-condition to their involvement and their contribution of funds. Everybody, including Chris Llewellyn Smith has tried to budge them on this, particularly the Americans. We have used the golf club analogy. We have said you must pay something to the base line in order to be able to contribute to the cream. The arguments have been deployed, they have been used, but the two outside associate non-member states, if you think of it, are in an enormously powerful bargaining position. The Americans, to their credit, have disappointed their high level physics community by refusing some of the longer range projects at Fermi Laboratory in return for making an investment in what is rapidly becoming the world project at the LHC. So I think there have been balances struck; I can assure you of that.

Sir Trevor Skeet

188. Professor Pounds, you are talking about the capital expenditure for the LHC and also a charge onto your current account, but surely you will be in negotiations now with the Director General of the Research Councils about that?

(*Professor Pounds*) I think this whole question, of how the OST and the DG and all of us given the present way in which the science vote is allocated—how within these arrangements will the United Kingdom ever be able to afford major new facilities. That is a question I think that at the moment has not been seriously addressed, but has to be addressed. I do know that the point is being raised for instance by our colleagues in the former Rutherford laboratory. Paul Williams is making that point fairly strongly. As I say, the question is one that really does have to be addressed fairly urgently.

Sir Trevor Skeet: Yes, but Professor Pounds, the GDP of the United Kingdom has been increasing quite considerably and therefore the United Kingdom can afford to pay more money towards science. Would it not be reasonable for you, in your negotiations with the DGRC, to insist that more money comes to you for the basic purpose of particle physics?

Chairman

189. You only meet Father Christmas once a year!

(*Professor Pounds*) I have actually had two opportunities now to insist on extra money for PPARC and it did not work either time! Obviously I shall try again but the Director General is not the sort of person that you can actually take that line with. I will try of course; I think we have to try and I hope that we will actually have persuaded at least one or two of you by the end of this whole process that in order for PPARC to do a decent job in basically delivering value for money in various areas, including particle physics, then we have to have the tools and one of the vital tools is to have access to the right amount of funding at the right time. I am not asking for more money over a period of time; I am actually asking for the ability to have access on a more flexible basis, basically David Phillips' point about lumpy funding.

Sir Trevor Skeet

190. Professor Pounds, another factor; when we had a look at CERN the other day we were impressed with the facilities that we saw, but it did occur to me that the host governments are getting away with it very cheaply. After all France, which is one of the host governments, is supplying all the electricity at a very cheap price. Can you not say that their contribution should be higher? And that of Switzerland also; having the hard currency should be an additional factor?

(*Professor Pounds*) Well, as one Member of a 19 Member club of course we have limited influence. We cannot dictate, we cannot insist, but what we certainly do—and I think the United Kingdom have a reputation for being really quite tough in these respects—is to try and argue along some of these lines. Some of you may recall that on the lead up to the LHC approval in December 1994, the United Kingdom and Germany actually stood out to the very last moment, in fact did win the argument to a degree which David Hunt interpreted in terms of saving the United Kingdom £70 million over the project. One of the challenges I have is actually trying to get hold of any of that £70 million. But one of the arguments we made, which was to an extent accepted, was that the host Member States do rather well in terms of their return. We recognise that and I think all Member States recognise it. In addition Germany and the United Kingdom have tried very hard, and with some success. We need to continue that; we need to continue to argue that, in several respects CERN could be cheaper.

191. Well, indeed. A final point I want to put to you, your subscription rate is £104 million per year for both ESA and CERN. How would you like these to be collected or handled? The Italian method, through the Foreign Ministry, through the EC or as you mentioned yourself, by a special fund? Do you have any other suggestions?

(*Professor Pounds*) My special fund was really to handle the lumpy nature of the domestic programme, but on your question about the internationals, I think there are arguments about it being logical to have the real cost of these programmes visible within the science budget. However, the disadvantages of that to science and the way we manage it, the way we try and get best value for money, outweigh those arguments. There is no doubt that the best solution from our viewpoint would be for those international subscriptions to be taken right outside the science vote and to be handled differently, as they are in almost every other country.

(*Dr Williams*) Chairman, may I add a little? Could I just say that this comes back on an earlier point that the Chairman made about the hypothetical conversation between our Chief Executive and the

[Sir Trevor Skeet *Cont*]
DGRC that by the mechanism that Professor Pounds has just proposed, that international subscriptions are taken outside the science vote, I think being a realist—and as an industrialist I have to be a realist—one would look to the Treasury and say, in effect, that mechanism has increased the science vote in the United Kingdom and I would gently take exception with something Dr Jones said a little bit earlier about the ratios of expenditure between ourselves and, she was saying, the other G7 nations. It is again a matter of record that this country is falling behind our G7 competitors in the sense of Government investment as well as industrial investment—on my side of the fence—in research and development. So the mechanism that Professor Pounds has proposed takes away an enormous volatility—£100 million in £1.3 billion—which is a huge fluctuation even for the DGRC, and at one and the same time pushes in the direction which I hope everybody in this room would be advocating, that this country needs to spend more on its basic science if it is going to keep up with its industrial competitors in the future.

Chairman

192. And takes away the foreign exchange fluctuations with it?

(*Dr Williams*) Yes.

Chairman: Mrs Campbell?

Mrs Campbell

193. Yes, I hear what you are saying, but surely the Government have tried to mitigate the effects of these fluctuations? My understanding was that the science budget is actually top-sliced with the fluctuations so that it is not all borne by PPARC? So why are you having so many problems if it is coming out of the science budget as a whole?

(*Professor Pounds*) I think there are two respects in which it would be better if it was outside the science vote altogether. The first is that within a limited science vote, we all lose of course when there is an increase in the top-slicing and the £18 million increase in the last two years in the CERN subscription cost us directly our pro rata share, that is 17 per cent of £18 million which is £3 million lost immediately to our domestic programme. So that is one loss, but I can tell you from personal experience that the other very negative impact on us is that it gives me a very bad starting point for negotiations with the DG about any additional bids I might wish to make. I have said to colleagues in the past that any attempt we have made in our first two years to get other help have been literally dead in the water, simply because everybody could see, and the DG himself could see, that he was forced by this very welcome top-slicing to give PPARC a big chunk of any flexible money before any other bids were considered. So, it would be better, as I have said, if it was all taken out.

(*Dr Williams*) I know the DG, by the way, has honoured the obligation in the White Paper to the nth decimal place, but at the same time as he has given PPARC the wherewithal to index CERN and the ESA subscriptions, for example, we were denied an additional bid on the INTEGRAL space mission, so again it is another example, but this time in the space area, of being denied the current funding to exploit the large asset that we are funding at tens of millions a year.

194. I know my colleagues want to come back to INTEGRAL at a later point, but may I just clarify one other thing and that is that when there is growth in the United Kingdom economy, that affects our international subscriptions. Is PPARC compensated for that in any way directly? If we get a 0.1 percent increase in the United Kingdom economy, do you get a 0.1 percent increase in your budget?

(*Professor Pounds*) No, there is no direct link there. In fact in a sense it costs us, because the CERN subscription and the ESA subscription are GDP related, so if our economy gets relatively stronger, that drives up the subscription we have to pay. I am not an economist, but it is surprising to a simple minded person that at the same time, and it has been true over two years, we have been losing out in terms of our CERN subscription (a) because our economy has relatively strengthened and (b) because our exchange rate has got weaker. Now surely that should not happen and hopefully over the long term it will not.

Mr Batiste

195. I have two questions. First on this question of funding, it has been put to us that one alternative might be to approach the European Union, particularly the Framework Programme, on the basis that their function is to establish European collaboration and certainly so far as the compulsory subscriptions to both CERN and ESA are concerned, these represent the most effective collaborations in science in Europe, always allowing for the fact that the membership of them all is not co-terminus, but that the Union might pay the subscriptions of Member States. Would that be an acceptable alternative if it were otherwise viable? I appreciate there are a lot of hurdles to jump on that, but would you see difficulties with that as a proposition?

(*Dr Williams*) I would turn the question back on you, if I may. Would you, as Members of the House of Parliament, wish to hand the responsibility for a significant element of your budget line, along with your other 18, 19 colleague Member States, to the European Union? It just seems to me to introduce an additional bureaucratic complexity in what is otherwise a very well proven system that has been working for decades and working very successfully for decades. I think it is fair to say that whilst we acknowledged that it was a very sincere attempt on the part of the Committee to explore alternative routes that might produce a solution to our problem, it is not one that we feel particularly drawn to instinctively.

Mr Thompson

196. Just a supplementary on that particular point first. Does that mean that you do not see advantages in this concept of separating off this international money that goes to CERN or ESA from the basic

[Mr Thompson *Cont*]

Research Councils' money that goes to research within our own community and elsewhere because—and I am speaking personally now and I am not necessarily referring to the European Union—I can see other ways in which the separation can occur? The more I think of it, the more convinced I become that the whole thing is being distorted by these international subscriptions and should not this Committee consider what the alternatives are and really explore this thoroughly, so I am really on the previous question?

(*Dr Williams*) I think for the record, just for clarification, we are strongly endorsing that the international subscriptions are taken outside the science vote, which is really your question, Mr Thompson. I think then whether this House in its wisdom decided to approach the European Union or the Treasury would be a secondary issue, but primarily it should be taken outside the science vote.

Dr Jones

197. If it did, who would be negotiating on behalf of PPARC?

(*Dr Williams*) It is not really a negotiation. There is a Treaty in both cases and most recently in the case of ESA, which I am sure we will come onto later, of course there was the ministerial meeting last year which produced adjustments by agreement between all the partners to the implementation of the Treaty, but in essence annually the way in which the CERN budget is drawn up is by Treaty and by agreement.

198. So basically you do not have much input into it in any case, so it would not make any difference to you if it was outside the science vote in terms of any influence you could bring to bear on those negotiations?

(*Dr Williams*) Influence I think is a different question. The mechanics are handled by an agreement almost by connotation by a lawyer or an actuary.

199. Would you not still wish to have some influence on negotiations—

(*Dr Williams*) Indeed.

200.—and would that not be reduced if it was taken out of the science vote?

(*Dr Williams*) Professor Pounds, do you have any reflections on that? I am passing the buck there!

(*Professor Pounds*) I am afraid my mind was still wondering about the EU as a way forward. In fact, I am a bit conscious of the fact that people take notes on what we say, do they not?[1]

Chairman: I think we will leave it there. We have another question on this, so we will move on.

Sir Gerard Vaughan

201. I would like to go back just a little bit. I have been to CERN a number of times and it has always struck me that we do very badly on the more commercial aspects, the tenderers. What I want to ask you before we leave all this, do you think we have the right mechanisms for getting the commercial benefits? I am thinking of things like the concrete, the steel, all the other infrastructure that goes into the very big projects. We do not seem to do very well compared to the others?

(*Dr Williams*) Could I comment on that and could I do, Chairman, what I should have done at the outset and declare an interest in the sense that Oxford Instruments participates in virtually all the types and size programmes, be it ESA or CERN that we are discussing today, so I would like to set that on the record. I think what you were alluding to, Sir Gerard, are things such as *juste retour* mechanisms which ensure a flow back of funds to the industries for the assembly and manufacture of goods. I think there are two issues here. I am by personal inclination very much a free trader and a level playing field man and I have the suspicion which I find it difficult to prove mathematically that mechanisms such as *juste retour* mechanisms ultimately increase the size of the bill in any given situation. The more that you tie the authority—in this case the CERN management—with requirements to place contracts in specific ways in specific countries, you are liable to eventually end up paying more rather than less and it becomes a self-defeating mechanism. If you then take my logic forward and if indeed you were also to subscribe to a free trade approach, then British companies must beat a path to CERN to pick up those contracts to which you referred. Indeed our current Science Minister, when he was Minister for Trade, purely fortuitously and coincidentally of direct value, led a trade mission to CERN two years ago that I was a member of which comprised 15 or 16 British companies. Most of them, including ourselves, are now vigorously active at CERN chasing those contracts. I think you would probably vote for British industry to pick up its fair share on fair competitive grounds rather than on some arbitrary *juste retour* which will ultimately cost the taxpayer more.

Chairman

202. Could we move on, if we may?

(*Professor Pounds*) Very briefly, Chairman, I think the problem is one of awareness and this is something we are very conscious of. We have in mind to develop what we call our technology plan and what this is going to do over the next few months, is like a microcosm of technology foresight. What we are going to try to do is make more of British industry more aware of the opportunities, because I think that while Oxford Instruments do quite well out of organisations like CERN, there are literally thousands of firms out there in places like Pudsey and so on which really are not so aware and I think we have to bring it to their knowledge.

Chairman: Absolutely right. I will do my level best on that. Trouble is, Oxford Instruments has not informed Cambridge! Dr Bray, do you want to come in on this?

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[1] I would expect PPARC to continue to provide part of the UK delegation to CERN Council, even if not directly responsible for the subscription, in order to provide scientific and technical expertise.

Dr Bray

203. The SERC in the past used to maintain an industrial officer at CERN specifically to look for opportunities. That has been discontinued by PPARC. Why?

(*Professor Pounds*) That is not strictly true. In fact there was a person funded for that purpose jointly with DTI. It was actually DTI who withdrew the funding. What we are trying to do now is to replace that person with someone who carries out a similar function, but we are looking at whether or not we can broaden such a function to include not only the opportunities within CERN but elsewhere within our programme. I do believe it is very much to do with increasing awareness of opportunity and that is where I think some of the modern techniques of multi-media and so on we can really take advantage of.

Chairman: We must now ask shorter questions and perhaps we might get shorter answers to move on to a number of the other issues. Mr Batiste?

Mr Batiste

204. A short question then. You have been asking or suggesting that the subscriptions could be reduced for exceptional circumstances—there is already a constitution for that—but given the fact that the reason for the increase has been the growth in the United Kingdom economy, what hope have you realistically got when the only previous derogations have been for quite the opposite reasons, for serious economic troubles within the country, for example?

(*Dr Williams*) I will be brief, sir. Our arguments, because of just those reasons, are weak but if you find yourselves as a management team, as we do, in a situation I would describe as being confined in a box, it is surely perfectly reasonable for us to push on one wall which is labelled United Kingdom Government and make specific requests and on the other wall which is labelled CERN and our partners. We are obligated to do that.

Chairman: Let us move on to the second part of that question. Mr Thompson?

Mr Thompson

205. We have spoken about industrial returns from CERN and I was simply going to ask whether the United Kingdom is getting its fair share of the intellectual returns because after all, when we visited CERN recently, we saw the tremendous enthusiasm of the researchers there, so would you like to say anything more about what might be lost, what the adverse effects might be; should we decrease our involvement with CERN? At the same time, may I ask whether there is a significant particle physics community in this country which does not depend on CERN? I have tried to be brief, as the Chairman has asked.

(*Professor Pounds*) The second part first. The fraction of the community that is involved in other programmes outside of CERN is probably about 30 percent. The dominance of CERN will increase as we get closer to the LHC programme, but I think the breadth of the programme is something that we are convinced is very important. The ability to actually expose British scientists and research groups to the CERN programme is really in a way what it is all about. There might be a Nobel Prize for someone at the end of it, but it might well be a figurehead leading a team of 2,000 people and I think we have to maximise the returns that occur all the way through this programme. From the objective output data that we have been able to get across our whole programme, we seem to be doing actually quite well. It appears that in terms of impact per unit of currency or impact per person involved, we do maybe a factor of two better than most of our main European colleagues, partners, competitors, whatever you like. So for the moment we are doing quite well, but I think the point we always need to emphasise is that much of the quality of what we are doing now is based on previous investment and that is why I think we have to be concerned about what we are laying down for our communities into the next millennium, in five, six, seven years' time.

Dr Williams

206. I would like to ask about the cap on particle physics expenditure? As I understand it, about a month ago the Council decided to impose a cap on the total expenditure and meanwhile to try and negotiate for a reduction in the CERN subscription. I feel quite pessimistic—although I am not an expert—about the prospects there and if there is no reduction in the CERN subscription, if it carried on going up ahead of inflation, would you still retain your cap and would that not then imply a continuing reduction in United Kingdom based particle physics?

(*Professor Pounds*) I think it would be unrealistic for any of us to say that the cap that we have for the moment, for planning purposes, put on the total spending on particle physics would remain forever at the level it is now. That would actually be quite unrealistic and you are absolutely right in linking that cap with the need to engage in negotiations with CERN initially—and it has to be CERN initially I think—and this was a view taken and recommended by our own particle physicists a year ago. We have first of all, to see if we can reach any agreement with CERN where they would recognise the greater benefits, if you like, of ensuring the United Kingdom community was able to continue to play a full part. We do recognise, as Dr Williams indicated a bit earlier, that we do not have a very strong argument for a semi-permanent, unilateral reduction in our subscription. But I think we have to go through that process. We have to argue it, probably with everything coming to a focus at the time of the LHC review in 1997 when the whole LHC programme is going to be assessed and we will know what the non-member contributions are. Then I think it will be a question for us, but for Government too, when—as I hope we do of course—we endorse our commitment to that programme, how do we then ensure that we are able to make it worthwhile?

207. Both within the PPARC and the particle physics community any talk of a cap must be wildly unpopular. What is the feeling within PPARC Council about the feasibility or the possibilities of doing with less?

[Dr Williams *Cont*]

(*Professor Pounds*) Within Council, it is one of the planks of Council's planning policy because Council for some time now has recognised that it is important to try to address this ratio (of subscription to domestic spend) I think maybe you referred to earlier. We have to somehow stop that ratio becoming more adverse and try, if you like, to turn it around. In a sense then the cap is just a part of the strategy, but I think it would be unrealistic to imagine that we could fix a cap now and live with it forever because, as you say, if nothing else happened and the CERN subscription was to continue to increase it could put us into a non-viable situation.

(*Dr Williams*) May I just add briefly that the policy, which was very broadly endorsed by Council at the last meeting, has now been put to the test in a very preliminary way in discussions both with OST and the Science Minister and with preliminary soundings at CERN. At Council's next meeting in two or three weeks' time we will be re-visiting this whole question about the precise implementation of the strategy, but as I said earlier, it is part of the strategy of trying to push on these two walls which are confining our programmes.

Mrs Campbell

208. It sounds to me as though you are putting yourselves in a straitjacket in order to improve your negotiating power? Are you?

(*Professor Pounds*) That almost sounds true, does it not?

(*Dr Williams*) Yes. We are in a straitjacket to an extent.

209. But it is a self-imposed straitjacket, because surely what you are doing is putting a cap on the particle physics part of your budget without doing the same thing to the space part of your budget?

(*Dr Williams*) Space has, in effect, been capped in a way within the science vote by the ever-rising cost of the CERN subscription in recent years which is why programmes such as INTEGRAL fell out of our programmes. We have been trying to level the playing field within our box, as it were, and explore not only the extremities of the walls but the boundary between the various other science programmes within the box.

Dr Jones

210. Should you not be looking at the expenditure on its merits and not just—

(*Dr Williams*) We are. We do, on its very full merits.

(*Professor Pounds*) The real cap, frankly, arises because of the under-funding across our whole programme. The thing Council has done—and I personally welcome it because I think in a very real sense it does show that Council is taking on the ownership of its programme, warts and all—is that it has looked at the programme and asked: "Where can we actually avoid this continuing decline", and not just, if you like, remaining on the sidelines and watching this decline. It therefore has taken action with regard to items like the Education and Training Programme and parts of the astronomy programme, including parts of space, and has recognised that it is possible for Council to reasonably handle those parts of its programme. I think that is it. However as I mentioned earlier, with the best will in the world I do not think we can handle in any adequate way the future funding requirement of the LHC programme. So I think we have a problem on the particle physics side anyway. So as to Council's thinking whether it is a mixture of strategy and tactics and science, I do not know, but it is probably not simply a preference which has been expressed for one bit of science over another bit; I do not think Council is in a position to do that. I think it is actually recognising where it is able to do something positive and effective and then isolating where it has a more difficult problem.

Mrs Campbell

211. It is nevertheless a decision which is causing a great deal of alarm amongst particle physicists?

(*Professor Pounds*) Yes.

Dr Jones

212. Just on that, it does not seem to me to be very logical to argue that you want this extra pulse of money to deal with the LHC and then to cap that part of the budget that you do control that could be used to put extra money in in relation to the domestic work associated with the LHC?

(*Dr Williams*) The problem is that that money cannot be used; we are genuinely short of funds satisfactorily to discharge our obligations under the LHC programme.

213. I am talking about the domestic programmes associated with the LHC?

(*Dr Williams*) They are inadequate in any of the various planning figures that we have put down.

214. Yes, but you are arguing for extra money to enable you to capitalise on the LHC investment, but at the same time you are reducing your own flexibility to put any extra money into that yourselves?

(*Dr Williams*) We are certainly trying to control a situation in which an ever-rising total element of our expenditure, which currently runs at £95.5 million, will always pre-empt any opportunity we have in any other aspect of PPARC's programmes for flexibility.

215. It does not mean to say you have to spend it, but you should be able to balance whether you want to spend it on that or whether you want to spend it on space or something else?

(*Professor Pounds*) Chairman, if I could just add, the capping has to be linked with the negotiation with CERN to try and redress that balance. Apart from that it really does not have any impact or value.

Chairman: We are talking here about the inevitable problem in which it appears that particle physics programmes and indeed astronomy has become ever more expensive day by day. Now Dr Bray, let us look at the future programme?

Dr Bray

216. Is the Large Hadron Collider the last Collider that particle physics can reasonably expect?

(*Dr Williams*) In the foreseeable future, yes.

217. What is the foreseeable future?

(*Dr Williams*) Well, it will come on stream towards the end of the first decade of the next millennium and its lifetime scientifically and as a piece of engineering must be 15 to 25 years, which takes us well into the next millennium. Although conceptions exist in the minds of particle physicists, many of whom are behind me today, about what might happen next, I cannot conceive of it realistically ahead of the middle years of the next century.

218. Has this not been the story all the way through, that particle physicists have said: "This is the last machine. Please can we have a nice big capital lump and we will then know that it has scored"?

(*Professor Pounds*) I would certainly agree with what Dr Williams has said about the timescale, so I think one would expect that the LHC would be a primary instrument feeding much of the requirements of ours and maybe the world's particle physicists' programme for the next 20 years. Beyond that it would probably be unwise to try and speculate, but it could be that this will be a milestone in complexity in the kind of scientific experiment that people will be interested in. This is already global and it is already, to most people's experience, I think, sociologically, organisationally and technically the most complex project that anybody has ever attempted. Well, I am not aware of a more complex or challenging one.

219. Polaris, Trident?

(*Professor Pounds*) It is a matter of opinion.

220. Yes?

(*Professor Pounds*) Whether that is right or not, I think it must be quite possible that someone will come up with other ways of really taking particle physics further forward. One dramatic further way of course, is to approach from a different point of view and if you go to, astronomical measurements of the cosmic microwave background you immediately take a leap of 10 to the power of 15 in energy and that is way beyond where humans could ever reach, so there are different ways of tackling these scientific problems.

221. You see, what we have at present is a certain field called particle physics which claims to offer fundamental understanding of the world and this becomes a career opportunity for a certain level of ability of physicists. It is an extremely difficult job market for young graduates today and where a particular class of graduates are offered a fascinating field technically in which to work, congenial company in which to do it and this claim to be tackling the fundamentals, is it not sort of writing itself an indefinite meal ticket for life within the science community?

(*Dr Williams*) Could I hazard a quick answer to that? I think at some stage we are, all of us, obligated to make a value judgment about the quality of science and the value of man's curiosity about matter and its origins and its structure and it is now a fact that in order to investigate those questions satisfactorily, we have been pushed to these ever-increasing complexities. I think also from an engineering perspective, and having had the benefit of reading your note, Dr Bray, which you kindly circulated, it is obviously true that there will come a point at which engineering will limit you in the conventional wisdom of accelerators in the present era and perhaps cosmological observation will take over. I think I am seeking to give you some comfort that perhaps this is not yet another notch on the ratchet of ever bigger, ever more expensive particle physics experiments for which the taxpayer will have to foot the bill, that things will genuinely have to change in the middle years of the next century.

222. There are two limitations. On the circular for instance there are the Synchrotron radiation losses and the view of Llewellyn Smith and of other senior particle physicists to whom we have talked is that this provides a fundamental limitation, which really means it is not worth going on to high energy levels after LHC. The alternative is linear accelerators and there there are major competing proposals being worked up in Germany, the United States and Japan on highly chauvinistic lines, where each of them is claiming to be bidding for a world machine, where each of them gives absolute commitment that it is their patch that is going to do it. That is not the environment in which the case was made originally for the rationalisation of particle physics in the 60s. It was not the environment that CERN was based on and it is really a question of the rest of the scientific community saying to the particle physicists: "For goodness sake, grow up and realise what the opportunities are in the rest of our field. Realise that we are tackling fundamentals in just a fundamental a sense as you are and we are actually tackling what is understanding, never mind what is understanding fundamentals".

(*Professor Pounds*) I think this is a very interesting point. It is an interesting academic point, but in my perspective, trying to make sense of the programme we have right now, I would come back to the point I think you made yourself, Dr Bray, that the question really we all have to be conscious of is that when we actually agree to take part in one of these major enterprises like the LHC, that is the time when we also have to make sure that we have the wherewithal to actually carry it through in an effective manner. That is why I have to keep coming back to the problems of funding properly the participation in a programme to which we signed up a while ago. That for me then is more important necessarily than the more academic question perhaps of what comes next and in a sense that is really going to be very difficult to predict.

Dr Bray: But the manner in which you pursue LHC and the funding for it is really locking yourself off from the questions which every other branch of science is looking at.

Chairman

223. I think it is recognised, is it not, that this is the case and you are struggling with your inheritance as best you may, but the real future that you are looking for is something outwith what you are presently engaged upon?

[**Chairman** *Cont*]

(*Professor Pounds*) If you were in a position now to offer me the additional funding to make sense of LHC on the basis of a promise I would make not to come back for 20 years, I would sign up to that now! However, it would not mean a lot, because I am only in this job for two more years!

Chairman: It would be a very cold promise by then, would it not!

Dr Bray: The difficulty with that is the long time scale, but if this really was the last and if you really were saying you have to get the absolute best out of this machine, then a totally different set of arguments come into the phasing round.[1]

Chairman: I think we will re-visit this at a later and longer occasion. Mr Thompson?

Mr Thompson

224. My own earlier experience studying science and years teaching physics taught me how high the standing of the United Kingdom is in matters of particle physics and astronomy. After all, it was only the cyclotron at the end of the Second World War when any other country had a look in on this at all. Everything else before, we had done. So our scientific standing is very high and is still very high. What is not entirely clear to me and possibly other Members of the Committee is whether our scientific standing is still high because of the tradition, or whether it is still high because the quality of our work continues in spite of the funding problems. So my question is, is there a risk or is there evidence that because of the funding problems our scientific standing is already decreasing or likely to decrease or would you not relate these two? In other words, are we beginning to lag in scientific standing or are we likely to do so? It is a very fundamental question, but I think you understand the point I am putting.

(*Dr Williams*) Yes, perhaps I could make a point first and then pass it to Professor Pounds. You have to start with the raw material, with the intellectual stock which in our schools is extremely high quality and there are gifted people, many of whom have grown up and are sitting behind and listening to what we say today. I do not think there is any doubt whatsoever that the intrinsic quality which made British science what it is today is still there. It is, however, a fact post-War that the world is vastly more competitive. I spend huge tracts and chunks of my time out in the Far East. I was in Taiwan and Japan two or three weeks ago and I was staggered to see what had been achieved in Taiwan with, by our standards, very limited intellectual resources and a very much smaller intellectual stock, but I think we all have to be cognisant of the risks that if we do not match our intellectual stock and our native ability by sheer hard cash we will eventually fall behind. I can think of few scientific areas of endeavour, even outside of very expensive things like particle physics, which is not hugely expensive and demanding on capital today. Nuclear magnetic resonance, things like this, very expensive indeed, but if you do not give a biochemist access to the most sharp scalpel, the finest tool that he or she can utilise, you risk putting he or she at a disadvantage relative to their Taiwanese, Singaporean or Japanese competitors. It is as simple as that.

225. So you think it is appropriate to use this term competitiveness in this area, which you have done?

(*Dr Williams*) Yes, there is no monopoly on brains in this country and East Asia is demonstrating that abundantly.

Chairman

226. Any point you would like to add, Professor Pounds?

(*Professor Pounds*) I would agree that we have great traditions and it makes us feel warm that Thomson, Rutherford and many of the great scientists were British. But that will not sustain for five minutes in the future and I think that is why we have to be concerned. We are actually looking ahead now in the context of LHC and CERN that we have spent a lot of time talking about, where unless somehow we are able to handle this requirement on our domestic funding then there will be a very substantial setback in the United Kingdom's relative role, reputation, returns in this field.

Dr Jones

227. I agree with the point about the need to be competitive and have investment in science, but is it important to have so much investment in this area of science in terms of our economic development? Could we not regard perhaps investment in particle physics and astronomy as the equivalent of our cultural investments in the Royal Opera House and maybe we should be looking for funding from, say, the National Lottery or something for any big plans? In terms of our interests as a country and our competitiveness and our economy, do we really need to be putting more investment in this area?

(*Professor Pounds*) We need to recall that we do, I think, about 5 percent of the world's research. The impact that we achieve in general in the PPARC areas is something like 10 percent, so we are actually doing quite well in that respect. However, given that we are only modest players in this whole global activity and in research and in spin-off and in everything the world is now a much smaller place, so we have to consider research in a world sense and therefore I think that what we should do as a nation is to try to identify which parts of the whole scientific activity we can make the best impact in. Now we can argue, fairly convincingly I hope, that we do make a good impact in the PPARC areas and that I think gives us a justification for continuing to retain our modest amount of money towards the 5 per cent National research effort.

Mrs Campbell

228. It is obviously true that CERN and ESA do not make their decisions in isolation. Can you tell me what sort of influence you have over the CERN/ESA decisions and how that is affected?

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[1] Professor Llewellyn Smith has stated that he expects the CERN budget to fall by at least 20 per cent a year after the LHC construction phase is completed (currently that would represent a £15 million pa saving to the UK).

[**Mrs Campbell** *Cont*]

(*Professor Pounds*) To take ESA, and move away from particle physics for a moment, that allows me to use an example that is very recent. Last week there was an occasion in Paris when all the Member States of ESA got together to make the selection of their next space mission, a mission called M3. That involved presentations by scientists, by engineers. The whole process took three days and at the end of it we were pleased with the selection that was made, a project called COBRAS-SAMBA because it happens to be one that maps on extremely well to United Kingdom interests. Another attractive thing for me is that it actually is a project that should appeal to particle physicists just as to astronomers because it addresses directly the question of the microwave background and how the universe came to be as it is. Retrospectively, we have looked at this whole episode of selection that took place, as I say, in Paris last week and numerically there were more Brits actually leading the discussions and influencing the final decision than from any other country. Happily, again, the person who was successful in selling COBRAS-SAMBA to the assembled meeting was a Professor called George Efstathiou from Oxford. So I think that on that recent example we still have major influence, notwithstanding that we have not been the most popular country within ESA during the last year or two and you might have heard some of that from Roger Bonnet, those who meet him last week, for different reasons. But I think in terms of our scientific influence we are still doing quite well.

229. And your influence in CERN?

(*Professor Pounds*) I think similarly in CERN. If you look at the United Kingdom scientists, the United Kingdom particle physicists on the key committees who are influencing the programme, again I think that you would find a similar picture.

(*Dr Williams*) Look at the number of Brits who are actually building the LHC. They are in charge of the project; they are good engineers.

(*Professor Pounds*) The DG is British as is the Chief Engineer, Lyn Evans. But so far, a lot of this strength is based on previous investment by SERC not by PPARC.

230. But these are people working on it, rather than people making the decisions about how the programme should go forward?

(*Professor Pounds*) We also provide chairmen of several crucial committees. There may probably be some of them who are sitting behind right now, so it would be invidious to mention names.

Sir Trevor Skeet: Professor Pounds, you obtained a certain amount of publicity in *The Times* of 22 April on "Fair Shares for Particle Physics and Astronomy". You can remember the article? In view of that, I ask you this question. What influence has PPARC on the programmes of international bodies such as CERN and ESA?

Chairman: As a matter of fact, I think you were so concerned with the article in *The Times* that we have actually asked that question already. In fact, Anne Campbell has done it. Do you have a supplementary on that question or shall we move on

Sir Trevor Skeet

231. In view of this, may I just ask you what is the change that you have noticed in the operations which formerly accounted for control when you were in SERC and now that you are in PPARC? You have one Director above you, of course, as opposed to the ABRC, but what changes have you noticed?

(*Professor Pounds*) Of course I am seeing it from a different perspective, because I was an academic until two years ago and now I find myself as a kind of bureaucrat trying to run things from the inside. If you are asking about the differences, the pros and cons, of the way PPARC is now trying to address its programme, there are clear drawbacks to the new arrangements and we have aired some of those today. We have less flexibility, we have less room for movement, but I think still that the big advantage that I hope that we will be able to realise to the benefit of the programme before too long is that we have a better focus. I think within PPARC we have people on Council, hopefully myself to some extent, who understand what we are trying to do and I think we should have a much better focus about on how to deliver good value for money than maybe a more diffuse body like SERC would have had.

Mr Batiste

232. May I follow that up and perhaps get some practical information, if I may? You made the point about your position, your presence on the Council and so forth. There are two Councils; one for CERN and one for ESA. Can I just get the practicalities of who leads on what? As far as ESA is concerned, it has to be Mr Davis from BNSC because they have the largest share of budget and there will be occasions when science is being discussed and you will therefore have a role on the ESA Council, but when it comes to the sub-committee dealing with science, presumably that is where PPARC would lead. Now who goes, who attends for Britain on that?

(*Professor Pounds*) Well on the Council, you are absolutely right, we only have one United Kingdom delegate and that is Derek Davis who is the Director General of BNSC and he represents the total United Kingdom interest, but when there is an interesting issue for science which is our pigeon, then either my colleague, Ian Corbett, or I would go as a second delegate and there is no restriction about ability to speak, influence and so on.

233. And so far as CERN is concerned, you would be the lead so who would attend to represent us on the CERN Council?

(*Professor Pounds*) On CERN we actually have two delegates and since we came into being they are myself and someone from the OST.

234. So would you ordinarily expect to attend most of the CERN Councils and ESA Councils in order to represent PPARC?

(*Professor Pounds*) We would certainly not expect to attend most ESA Councils because quite a few ESA Councils do not have any science interest, but we would always wish to be fully represented at the lower level at ESA which is the Science Programme Committee where we have two delegates.

[**Mr Batiste** *Cont*]

235. Do you feel that as far as you are concerned you should attend or not?

(*Professor Pounds*) I do sometimes go along to Science Programme Committees but it is not thought that I am quite the right sort of person to be a delegate. But I go along and speak at times and I seem to be very welcome. Within the CERN Council, I know it has actually been mentioned that some people feel I have not turned up quite as often as I might. My response to that is that, in fact, I went to every meeting on the critical run up to the selection of LHC in December 1994. Since then I have missed three Committees of Council over the subsequent 16 months, but on every occasion I have been to the United Kingdom briefing meeting where we get, if you like, our act together and also ensured that there was a suitable substitute—sometimes I think actually a better substitute—from our particle physics community to take my place. I can honestly say I do not believe the United Kingdom position has been in any way weakened at any time through the fact that on three occasions I felt it was more useful for PPARC for me to be somewhere else; once in Japan, once actually in ESA and once during SET 96 giving a public lecture in Newcastle.

236. The nature of these international collaborations is really quite important. These are obviously, in terms of your Research Council, the pre-eminent parts of your brief and obviously you have to make a priority about where to attend, but would I be right to say that you would regard the need to establish good relationships at a personal level between yourself and your opposite numbers from other countries, and yourself and the bureaucracies of the two organisations, as being an important part of your role?

(*Professor Pounds*) Absolutely, I think that much of the real work in organisations like CERN Council take place behind the scenes. You have to discuss and try to reach some understanding with the other key delegations and I have found it quite striking that the key delegations are really quite small in number. It is usually the Germans, the French, maybe the Italians and the British. Typically the other members tend to quietly go along with whatever is agreed.

237. In relation to the decision on INTEGRAL made for the reasons which have been described already, it was obviously a great blow to the space community in Europe because everyone perceived INTEGRAL as being British led and there were expressions of shock everywhere around Europe when we pulled out of it. How would you think it best to communicate the decision with our collaborators in these things to minimise the damage to our reputation as a collaborator that would flow from those decisions?

(*Professor Pounds*) I described INTEGRAL after the event as a scientific and political disaster, because the outcome was that we lost a lot of our reputation as a reliable partner within these emerging collaborations in Europe and we finished up by still spending £65 million on the project through our ESA subscription without actually getting much out of it. I have tried to carry through a kind of damage limitation exercise so we have now managed to get a few experts into the programme, but at a very modest level. What we are doing in the future, starting with Rosetta, moving on to COBRAS/SAMBA and FIRST is to start to plan much earlier. What we have to do, I think, is to try and set aside the funding at some suitable level, but also to talk within our community about priorities, to have some sort of pre-selection and then, if you like, to guide our groups so that when they go and talk to collaborators elsewhere in Europe they have some idea of their chances of funding if they are successful in bidding for an experiment or whatever on the next spacecraft. So we have tried to be much more proactive, I think reasonably successfully in Rosetta. I think we now have a fairly reasonable stance on Rosetta where the selection ESA made was precisely coincident with what we wanted and at a level that I think we can reasonably afford. That is the way we have to do it and I think it was badly handled in INTEGRAL, but that originated in the change over period.

238. So with hindsight you feel that the announcement of INTEGRAL and the (from SERC) communication of our decision to our partners could actually have been done in a better way that might not have caused quite so much damage, because for example certainly some of the space hardware people believe they have lost vital contractorships on other projects as a consequence of it?

(*Dr Williams*) May I comment on this? It might embarrass Professor Pounds. I think that faced with an immediate and very difficult decision, which was basically on the plate, delivered to us on day one of PPARC, Professor Pounds personally, following your earlier line of questioning, communicated the bad news and as far as one can in such circumstances, I believe communicated it very well and very effectively and personally with a great degree of courage. I think the regrettable fact was that here we had formed for the first time a Particle Physics and an Astronomy Research Council and almost its first act was to cancel a space mission and you just cannot disguise the damage that something like that does. It is not about communication; it is just a fact.

(*Professor Pounds*) Chairman, if you would allow me to say the one thing that I might add to that, which is that at least no-one accused me of prejudice after that, because I was seen as someone who, if you like, was cutting off one of my own legs!

Chairman

239. Just a point to extract from Mr Batiste's questioning. Obviously the relationship between that whacking customer of yours, if we can call it that, CERN and the equally whacking organisation ESA, would require a relationship between PPARC and CERN and ESA which was of the most effective form possible. Are you content that the relationship is one of that character? I have in the back of my mind that the Chief Executive of PPARC is someone who could call up the Chief Executive of CERN or ESA or whatever and ask him to come over on Monday or at once because he wants to see him. Are you in that kind of relationship?

(*Professor Pounds*) I think there is no doubt. The person at CERN is Llewellyn Smith, the Director General, and of course we have good relations with him. Although not a particle physicist, I have known

[**Chairman** *Cont*]

him for many years and the key person in ESA is Roger Bonnet who is the Head of their Science Programme and I do know them both well enough to behave just like that.

240. So you would be just as available to them as they would be to you?

(*Professor Pounds*) Absolutely, yes.

241. Can we now inquire into responsibilities? I think perhaps a question to Dr Williams? Can you describe briefly to the Committee how you divide the responsibilities between the Chairman of PPARC and the Chief Executive of PPARC; what are the respective responsibilities, and perhaps you could give us your view, both of you, of what the responsibilities are or should be of the Director General of the Research Council?

(*Dr Williams*) Yes, I can give you a very straightforward answer on which I am sure Professor Pounds will wish to amplify. If I take you back to the old Research Council structure, then I would describe Professor Pounds' current position as Chief Executive of PPARC as being very analogous to the old Chairman of Council who, of course, was always a practising senior leading academic in the discipline concerned. What then happened in the post White Paper era was that in the creation of the new research councils, which I think is the thrust of your question, a new structure was introduced in which animals such as myself were brought in from the world of industry as—and I would add this very clearly—a non-executive Chairman, that is how I would describe it, from the industrial world. Therefore it is very easy to describe Professor Pounds' responsibilities; they are very analogous to the old Chairman of Council in virtually every role and every respect, to which is added a function—to whit, mine—which is very analogous to a part-time nonexecutive Chairman of a publicly quoted company. In that case, one is looking after the shareholders' interests, ensuring that the right questions are asked, the right due diligence is done, the Board Meetings in that case are conducted properly and rigorously and I see my role at PPARC as very much that, that the business of Council is done professionally, that communication is handled always honestly, sometimes with imponderable effects as we have seen recently, and that in all respects due diligence, fairness and honesty and openness pervades the whole of Council's business. The complexity in the new structure is of course the role of the DGRC. We moved from an era where we had the ABRC, with the research councils feeding up into it, into an era in which the DGRC would advise the Minister on all matters to do with all six, now it is seven, research councils. I have to say that in the very early days a structural tension which is inherent in that system made life somewhat difficult for the DGRC, for his chief executives and also for the non-executive chairmen. I do not think that is too surprising and I think much more has been made of it than perhaps has been merited. It would be a great surprise to me from an industrial perspective if a management structure that cannot be written down sensibly on an organagram could easily be put into practice straight off the bat in a new research council structure. So there were tensions, there were difficulties. I would also say, very positively, that the level of understanding now between the DGRC, the non-executive chairmen and the chief executives makes the system and the structure work vastly more effectively than it did two years ago.

242. So you are more content now than you certainly were?

(*Dr Williams*) It is not a structure I would recommend for a PLC but it can be made to work and it is working more effectively now than it was two years ago.

243. Right, and Professor Pounds?

(*Professor Pounds*) I would go along with most of what Dr Williams has said. Our relationship is one I am very happy with actually—

(*Dr Williams*) He has to say that!

(*Professor Pounds*) He offers just the kind of advice and guidance that is very valuable to me. With regard to OST, I think again that all the research councils have worked out an effective way of operating within the system we find ourselves in. If I could just mention one aspect, however, of OST's involvement in our programme which I believe is less than ideal, that is where the existence of OST does make it more difficult for someone in my position to speak directly, when appropriate, to a Minister and I was actually quite conscious of that as being not, it seemed to me, in anybody's interest generally speaking in the run up to the review of the ESA programme in Toulouse, because I did feel then that if I could have got Ian Taylor in my local for half an hour it would have been quite useful to both of us.

Dr Bray

244. Is that not pretty near the nub of the problem, that in the old days with the ABRC, the broad allocation of the science budget and the addressing of questions of principle were tackled in a collegiate way, certainly with the Chairman speaking directly to Ministers, certainly with a representation of non-executives there in the sense of the non-research council members of the ABRC, but in a climate where a balanced view could emerge from within the science community, the rationale having broadly being accepted and quite difficult decisions having been taken? We then moved to a situation where you get the executive role of the DGRC thrown into that communication network in an environment which does not really fit on the Ministerial side or on the science side and the interfaces between them?

(*Dr Williams*) I think what you say, Dr Bray, is true, but I draw your attention to the Hansard record of the White Paper debate in which the House urged that sufficient powers would indeed be given to the DGRC in order to enable he or she effectively to conduct their job and the thrust of the White Paper in terms of the restructuring, the introduction of non-executive chairmen and the role of the DGRC was to move much more towards—dare I use the words?—an industrial management type of structure and situation in which responsibility is indeed vested much more in individuals than in collegiate bodies, moderated then by collegiate bodies. A recent development which I think is very positive is a series of dinner meetings between the DGRC, the Chairmen of Council and the Science Minister which

[**Dr Bray** *Cont*]
have taken place, which is a very useful forum in a collegiate sense as you refer to for exchanging ideas and defusing tensions that always arise in such situations.

245. I will look again at that debate, but looking at the future development of the system, one really needs a structure which is capable of functioning independently of the particular strengths of the personalities involved if that is to be an enduring and reliable thing. With that objective in view, are there changes you would like to see made?

(*Dr Williams*) Perhaps I should hazard a response to that.

(*Professor Pounds*) Perhaps I should not!

(*Dr Williams*) In the sense that are there new bodies, new collegiate organisations to be pulled together, I would honestly say not and I suspect there is many a silent nod going on behind me that the last thing science in this country needs right now is another body, another watchdog, another layer and I would strongly advocate the opposite to that. I think you have the ingredients in your hands; a strong DGRC, non-executive chairmen drawn from industry, chief executives who are leading scientists in their various fields. All the ingredients are there, and as I said earlier it is now working vastly better than it was two years ago.

Chairman

246. May I ask how frequently, in terms of the operations of PPARC, you actually see the DGRC?

(*Professor Pounds*) I think the links there are really very effective. We have regular meetings once a month of all the chief executives.

247. Of all the chief executives; and he chairs that Council?

(*Professor Pounds*) He generally chairs that and we have a very free exchange of views about usually many things, but in addition to that there are bilateral meetings as and when necessary. So there are few problems there at all.

248. You have sufficient rapport on what you need to have a rapport with him and with your colleagues?

(*Professor Pounds*) We do communicate very frequently. In fact yesterday I held off writing a fifth letter to Sir John Cadogan just feeling like I was overdoing it.

Chairman: I might agree with that!

Dr Bray

249. On the question of going in the opposite direction, what I had in mind was not adding another layer, but removing one. That is to say, having the Chief Scientific Advisor being the sole scientist at that level, not having a DGRC, but the Chief Scientific Advisor fulfilling the same kind of role in relation to allocations between or influence over individual research council budgets as he would have over MoD research or Transport research or other research?

(*Dr Williams*) Dr Bray, could I just avoid the question? I think it is, in a sense, an unfair question to ask Professor Pounds and myself at this point and really to go back to the White Paper Realising our Potential and the structure that you have today is precisely what was laid before Parliament those years ago and it has been implemented as a strategy.

Sir Trevor Skeet

250. Dr Williams, could I just ask one question on this; it is a very practical one? The Director General of the Research Council comes from the oil industry. He has, I would have thought, very little experience in particle physics and astronomy. Do you think that constitutes any restraint in his dealing with particular matters when dealing with PPARC?

(*Dr Williams*) No, Sir Trevor, I do not. As you know, Sir John for many years was associated with the old SERC, with Science Board, Council and so forth and indeed many of the issues that we are confronting today have been round the mill at least once or twice in Sir John's lifetime. I would say people like me are the newcomers. I hazard I was the person invited because I was the only industrialist who could spell particle physics and astronomy!

(*Professor Pounds*) I would agree with that. I think that Sir John understands well enough particle physics and astronomy to be effective in his job. May I just add a point I feel is relevant to OST, not particularly to the Director General, and that is that I believe there is a role that has still perhaps not been effectively addressed in bringing together interdepartmental needs, requirements, programmes in science across the whole of Whitehall, and that is something where I think progress needs to be made.

Sir Gerard Vaughan

251. It all sounds rather satisfactory the way you have put it. May I just ask you about the composition of your own Council, because it is rather different, as I understand it, from the previous SERC compositions? Am I right in thinking that, for example, financial decisions are all made by the Council itself and not by the sub-committees working for the Council? It has been suggested that you would be much stronger if you had the chairmen of the sub-committees actually on your Council and that the appointment of people, each person in his own right, leads to an imbalance actually in your Council?

(*Dr Williams*) I think just as a point of information, as a relatively recent instigation, the chairmen of our two major sub-committees are always in attendance at Council meetings and the way that I try to ensure that Council business is conducted gives every person around the Council table free reign and a free voice. Still we are attempting to take care of the possible imbalances that you refer to. I do not believe in any sense, shape or form that the nature of the decision making process reflects any imbalance in Council membership or indeed that there is a simple stratification along specialist lines.

252. It has been suggested, I believe, that problems with the community generally, when you make slightly controversial decisions, would be much easier to manage if you had the chairmen of the sub-committees on your body?

[Sir Gerard Vaughan *Cont*]

(*Dr Williams*) That is a sensible point which I will ask Professor Pounds to comment on in a minute. As I say, they are in attendance; it is an issue that has been raised by my own Members of Council as well from within and it is obviously something we will take note of, seeing you have raised it again today.

(*Professor Pounds*) I think the practical requirement is one of communication. We have to try to ensure that Council, in making its headline decisions on policy and on funding, needs to be adequately aware of the pressures and potential within the science community and there were things that we did not quite get right in this in the first year or so. We followed too strictly, I think, the guidance we inherited from the White Paper that the Council should be a very small, compact, independent body and we did try to function for the first year by just having this small group of a dozen people, including both of us, but I think we have now realised that in fact there were weaknesses in that in relation to informing Council. That is why Dr Williams and I agreed a while ago that we would always have the committee chairmen there when there was relevant business. They will only be not there when there are matters where they have nothing really to offer.

Chairman: Right, thank you for that answer. I think that where we have reached 6.00 o'clock or just after, I would like, if we may, to have just one more question about Observatories. Mrs Campbell?

Mrs Campbell: I have a special interest in this as you may appreciate.

Chairman: That is a declared interest.

Mrs Campbell

253. Yes, because one of those is situated in Cambridge. The Royal Observatories have been praised as providing very good support for observers and the recent review has proposed the opening of tendering for the management of telescopes and supply of instruments to all competent suppliers. I wonder if you feel the interests of observers will be looked after under this process and whether there is any practical organising entity looking after the current and future interests of United Kingdom astronomy as a whole?

(*Professor Pounds*) I believe the interests of observers in terms of effective use of existing instrumentation will be adequately catered for by what basically we have already done, and that is to give greater delegated authority to the heads of the two sites where the astronomy is actually carried out. I think the real question that does involve substantially the Royal Observatories in the United Kingdom, and what might succeed them, is how do we maintain the quality of these overseas facilities over the years ahead. That is where the technical base is needed. I believe that it is very important that we do not lose some of this expertise in the competitive process, that is now going to develop. I think all PPARC can do, having gone through this process, is to welcome the fact that we now at least have the opportunity to take it forward. We believe we know what we want. We have developed, if you like, a kind of shopping list of new cameras, spectrographs and so on needed to keep our telescopes competitive in a world class sense over the next five or ten years. We know what we can afford and now I stress that I am looking forward to competitive bids from wherever. One thing, finally, that we do welcome in the way in which the announcement was made by Ministers, is that it was made without strings so that there are no restrictions in principle as to who can bid. So we have maximum competition. Personally, I would be surprised if there are not strong bids from the same sort of people in some sort of recognisable groupings, that have been delivering these spectrographs and cameras in the past, because they have obviously a great advantage in terms of expertise, but we cannot predict that.

Chairman

254. Thank you for that and thank you both for coming and for giving us a lot of your time and for answering our questions. I think I should just conclude by obviously saying that this is, for us, our first thorough look at a Research Council in the orderly way in which we would seek to progress and we have done so obviously because of the scale of the commitments in which you are both engaged as well as the magnitude of the science in which you are both engaged, but it will not at all surprise you if I say that much of this is still of extreme interest to the Committee as newcomers in this area as well. We have a longish learning curve to undertake, but we are grateful for your assistance in helping to unravel some of the fairly knotty issues with which you are engaged. We are grateful for your time and opportunity to do so.

(*Dr Williams*) May I just respond by saying that we have been, and I speak on behalf of the community, very impressed with the diligence with which you pursued your task and we are indeed very grateful for the effort you have put into it and all the time you have given. We are very conscious of that. We look forward to your report with great interest.

Chairman: I trust it will not be a collider! Thank you very much.

Letter to the Clerk of the Committee from Professor Ken Pounds (15.5.96)

LIAISON BETWEEN PPARC AND ILO AT CERN

PPARC staff, specifically the formal delegates to the CERN Finance Committee, liaised closely with the Industrial Liaison Officer for the UK when this post was funded, (by DTI and industry) through the High Energy Research Facilities Unit at RAL. This liaison was on a day to day basis concerning particular contracts at CERN, aimed at aiding UK companies bidding for these contracts and in helping CERN to identify relevant companies. More policy orientated liaison occurred on general issues affecting UK companies, particularly when the CERN Purchasing Policy and Procedures were being reviewed in 1992 and 1993, with the UK having a major input to that review.

The DTI part-funding for the Unit finished at the end of its three year grant in June 1995. PPARC, DTI and EPSRC (who were also partners as the Unit addressed ILL and ESRF), had long discussions on the future of the Unit when it became clear that it would not become self-financing through industrial subscriptions, as had originally been hoped by DTI. PPARC and DTI tried hard to find a means of providing funding for a future activity that would serve the needs of PPARC, in fulfilling its strategic objectives, of CERN and of industry. Eventually PPARC decided to go ahead and establish its "Unit for CERN" at CLRC. DTI decided not to contribute to this and neither have EPSRC. Hence the new Unit does not address the needs of industry relating to ILL and ESRF.

The PPARC funded Unit helps CERN to identify relevant UK companies to contact for market surveys, is responsible for the UK portion of the CERN supplier database and helps industry with general queries on bidding for contracts at CERN. PPARC staff also assist companies with advice on specific or general issues and provide information to interested companies on calls for tender that are due in the near future from CERN. The Industrial Liaison Officer funded by the Unit is a CLRC staff member contracted for a limited number of days a year. A representative at CERN is also funded by PPARC through the Unit to work one day a week to help UK companies get access to the smaller contracts which make up a large proportion of those issued.

The current annual cost of the Unit is £20k; this figure includes the position of Industrial Liaison Officer, some technical engineer time at CLRC, secretarial assistance, the representative at CERN and overheads.

ESA

The correct balance between the ESA subscriptions (ca £38.5M pa) and the UK domestic programme is achieved when the UK community is able to exploit the scientific and technological opportunities offered by our membership of ESA. This means that the UK is able to provide leading edge instrumentation for ESA missions and to participate vigorously in the data handling and sceintific analysis, subject always to the rigours of peer-review selection. To do this the UK must not only invest in current missions, it needs to maintain the infrastructure and R&D programme which enables it to be competitive in winning premium scientific positions in future missions. It should also be able to participate at a modest level in non-ESA missions, always of the highest scientific quality, where these are complementary to ESA missions and help maintain the UK community at the scientific forefront.

The annual funding levels necessary to achieve this balance have been arrived at by detailed "bottom-up" analysis and are given below, with the current (1996/97) figures for comparison.

	£M	
	Optimal	*1996-97*
ESA missions	10.0	8.5
non-ESA missions	2.2	1.2
infrastructure	5.0	4.5

It is generally recognised that a planning figure of about 30 per cent of the ESA subscription (ie about £11.5M pa) affords optimal participation in missions and data reduction: the above figures provide this level of support. This view was supported in a statement by Ian Taylor following the ESA Council in Toulouse last October.

GROUND-BASED PROGRAMME

The ground-based astronomy programme has been "international" since 1974 when the Anglo-Australian Telescope (50 per cent UK) was inaugurated. All telescopes except UKIRT (Hawaii) have been shared with international partners since the early to mid-1980s. The major new investment project (the Gemini twin 8 metre telescopes) had to be international (the UK has a 25 per cent share overall) because no single country, not even the USA, could contemplate such a large investment without collaborators.

The problem is not the "internationalisation", which has been advantageous for the UK in giving our community guaranteed access to world-class facilities which the UK could not otherwise afford. The problem is that the cost of maintaining world-class facilities inevitably takes an increasing fraction of a total budget which is declining in real terms. The UK's international partners have proved active allies in seeking to drive down operation costs, and have been very supportive in exploring innovative ways of making the facilities progressively more cost effective.

It is the cost of meeting existing high priority commitments—not just in ground based astronomy—within a shrinking overall budget which has put growing pressure on the funding available for new projects. International collaboration has been a benefit because it has allowed the UK to secure cost-effective participation in projects it could not have afforded alone, and so has helped improve the scientific return to the UK from the limited funds available. This is not, however, a process that can continue indefinitely and the UK is increasingly living off the benefits of past investment.

INDUSTRIAL SPIN-OFF

Peter Williams' note to the Committee summarised the industrial spin-offs from PPARC physics in the areas of accelerators; the semiconductor industry; medicine; industrial uses such as food sterilisation and nondestructive testing; research uses, such as synchrotron radiation research application in x-ray crystallography; super conductivity; and software, computers and electronics—citing as one example the fact that World Wide Web was developed by High energy physicists at CERN.

The leaflets supplied to the Committee "Helping Industry—the application of PPARC funded research" and "Basic Science helping industry" give examples of spin-off from PPARC research in dentistry, in energy and communications, healthcare, defence, materials and aerospace. We can, of course, supply more details of these and other examples if you wish.

We are increasing our efforts to encourage the promotion of industrial benefits, even under a constrained budget, because we recognise the considerable gearing which relatively modest funding can achieve. Our Special Scheme to promote university/industry collaboration (PIPSS—described in our Memorandum) is planned to run at about £700k pa, but we are confident that the benefits which will accrue from that collaboration will be much greater. At that level of funding you will see that its cost will have only a minor impact on the major research programmes. (The same arguments apply, of course, to the Council's wish to increase its efforts in the public understanding of science.)

ATTENDANCE AT CERN COUNCIL AND COMMITTEE OF COUNCIL MEETINGS

The formal attendance from the UK at CERN Council and Committee of Council is the Chief Executive of PPARC, who leads the delegation, and the Director, Research Councils, OST (currently Mr Adrian Carter). There are 2 Council meetings and 4 Committee of Council meetings per year, a total of 4 and 8 meetings respectively since PPARC was established. Of these meetings, I have attended CERN Council on 3 occasions and Committee of Council on 5 occasions. On all other occasions I was represented by either an appropriate member of PPARC staff or by the Chairman of the PPARC Particle Physics Committee. The Director, Research Councils, OST has attended all the Meetings.

This practice differs from that under the SERC, where the formal representation was the Chairman of SERC, who led the delegation, and the chairman of the relevant SERC Board, latterly the Particles, Space and Astronomy (PSA) Board. OST did not then have a delegate position.

APPENDICES TO THE MINUTES OF EVIDENCE

Letter to the Clerk of the Committee from Professor Peter Kalmus (22.11.95)

HOUSE OF COMMONS SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY:

INQUIRY INTO THE PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL

I welcome the opportunity to give written evidence. I should first declare an interest in this area. I am a university physicist and have carried out research in particle physics for about forty years. I am currently on two committees of PPARC: its Education and Training Committee and its Panel on the Public Understanding of Science and Technology. In the past I have been a member of two relevant Boards of the former SERC, and was at one time scientific adviser to the UK delegation to CERN. While it is therefore natural that I should be a supporter of "big science" projects, I should point out that I am Head of a Physics Department. Our Department carries out research not only in particle physics and in astronomy, but also in "small science" including areas of condensed matter, medical physics and theoretical physics, so I am fully aware that we need to have a balance between the legitimate claims of small and big sciences.

Let me first comment on the specific questions: It is important that UK scientists have the opportunity to participate in big science projects. I am not suggesting that UK scientists should have the automatic right to participate in every large venture, but international sharing of large facilities is an efficient method for UK scientists to gain access to world-class equipment.

The Large Hadron Collider project, which is given as an example, will be the spearhead of European (and indeed world-wide) particle physics for the first part of the 21st Century. UK scientists were involved in its conception and in the planning of its experimental programme from the start and some are playing leading roles in the programme. The project was evaluated carefully not just by scientists and engineers, but by the funding bodies and ad-hoc committees advising governments. In the UK, LHC was balanced within the whole programme, and other attractive areas in particle physics (such as high energy muon and neutrino physics, and proton-antiproton collider physics in which UK physicists had previously had major roles) had to be sacrificed to allow partcipation in LHC.

I see no reason why UK scientists should not be able to exploit such collaborative facilities in the future: we have done so in the past. I can give a personal example. The discovery of the W and Z particles at CERN which showed that two of nature's fundamental forces, electromagnetism and the weak interaction, were actually aspects of the same unified force was regarded as the major achievement in particle physics in the second half of this Century. The discovery of the W and Z carriers of the weak force, and the earlier discovery at DESY of the gluon, the carrier of the strong force, shifted the centre of excellence from the USA to Europe. UK physicists played prominent roles in both projects, and although the Nobel Prize for the W and Z went to an Italian and a Dutch physicist who had made the biggest contributions to this venture, some of us were fortunate enough to have our contributions recognised, for example by medals and by congratulations from the Prime Minister.

In astronomy too, UK scientists have played leading roles in big collaborative ventures, both with large telescope projects and with space missions. Again I cite a local example. A colleague in my Department is Principal Investigator (=chief scientist within an international collaboration) of one of the four instruments on the Infrared Space Observatory, ISO, which has just been launched by ESA. He has devoted many years to this project, and was able to do this together with his teaching and other duties ass a UK university teacher. He too was rewarded with a medal for previous achievements with the Infra-Red Astronomical Satellite IRAS. The UK has been pre-eminent in X-ray astronomy from satellites, and there are many other examples. So UK scientists can exploit big science projects, which give us access to the best facilities in the world, and compete for their use on the merits of our proposals and our track records.

I believe that CERN is managed well. It is certainly user-friendly, and far less bureaucratic than many EU programmes stemming from Brussels. The CERN governing Council consists of representatives appointed by the governments of the member states. They appoint the Director General (a UK scientist at present) for a fixed term, and approve the appointment of senior management, also for fixed terms. CERN is advised by various committees consisting mostly of scientists from the member states. The budget is shared between member states by formula which is (roughly) proportional to their national wealth.

The UK subscription to CERN is attributed to PPARC. Whilst there is some logic in the subscription coming out of the same pocket as the funding for its exploitation, it does lead to the anomaly that when we have to pay more, for example for currency exchange reasons, we have less money for equipment, technical and research staff, and for travel needed to order to exploit the use of CERN. Other Member States do it differently, and I believe it would be in the interests of your Committee to investigate this and see if one of the other methods would serve us better. Some countries fund CERN from their equivalent of the Foreign Office, perhaps because of the political implications—in addition to its scientific excellence, they regard CERN as a shining example of international cooperation, and cheap at the price. It was after all formed over 40 years ago as a collaboration between countries that had recently been fighting each other in the war. At present there is an imbalance: we really need a higher ratio of exploitation budget to international subscription. I believe the situation is even more acute in ESA.

PPARC does not have the power unilaterally to reduce the international subscriptions since our participation is by inter-governmental agreement. Whereas government is right in checking that these organisations are run efficiently, they should take some responsibility for the subscriptions. A comparatively modest increase in UK funding into the exploitation of CERN and ESA, would make us more equal to our international partners who spend a higher fraction of GDP on science, and allow an even more efficient use of these world-class facilities.

I believe that PPARC's structure is appropriate to its research portfolio. As mentioned, I am on two committees, and I have been satisfied that they do worthwhile tasks in a reasonable manner. Members of Council meet committee members once a year for progress reports and general discussion, and have taken steps to sound out their scientific community including research students. I am less familiar, but also less happy, with the management of one of the other Research Councils. Obviously, since the Councils are relatively new some time must elapse before we can evaluate their performance fully.

I will now make a few comments about the PPARC activities in the committees on which I serve. These cover areas in which PPARC can definitely contribute to objectives of the White Paper which set up the new councils. The Education and Training Committee, spent the first year gathering information, and then recommending future policy to Council. Amongst the matters discussed were research students, research fellowships (postdoctoral, advanced and senior) and the balance between these; demands from various sectors (industry, academia, finance) for PhD science graduates, training benefits of big science, and career paths. A report of the E and T Committee has been published, and in general our recommendations were accepted by Council. 10 years ago a national survey showed that the "PPARC areas" attracted school leavers into physics, and this survey is now being repeated.

The Panel on Public Understanding started with a free ranging discussion, and later recommended certain specific lines. It is aware that public understanding and awareness of science and technology is now being addressed more vigorously than in the past by a number of bodies, as well as by many individuals. There was some emphasis on activities involving schools: both pupils and teachers, but also the view that members of the public at large, including their elected representatives, deserve explanations of why science and technology are exciting and important. Recommendations accepted by Council include encouragement that research grant holders spend up to 1 per cent of their grants on public understanding work, the active participation of research students and fellows in such activities and the setting up of a competitive awards scheme. In the latter bids of up to £10,000 were invited (from anyone) for schemes which would help public understanding. Over 100 bids were received, were judged by a panel, and about a quarter of them were funded amounting a total of over £100,000. Some of the winners were invited to describe their projects at a Press Conference at the annual meeting of the British Association for the Advancement of Science in Newcastle in September 1995.

Obviously I have only been able to give some flavour of PPARC activities, and even so this letter is longer than I would have liked for the attention of busy people. I would of course be happy to give oral evidence if your Committee so wished.

Letter to the Clerk of the Committee from Professor D Saxon (30.11.95)

I am writing to you in a personal capacity, based on my experience as the retiring (Dec. 95) chairman of the PPARC Particle Physics Committee, having been chairman earlier of the SERC Particle Physics Committee from September 1992, I have this year presented plans to PPARC Council for the development of UK Particle Physics between now and 2004, a period including the LHC detector development and construction, and also presented proposals on the future relationship between PARC and CCLRC in the field of Particle Physics. I also serve as part of the UK delegation to CERN Council, and in a personal capacity on the CERN Scientific Policy Committee and the DESY (Hamburg) Physics Research Committee.

Prior to the approval in 1994 for the LHC project at CERN, the SERC and subsequently PPARC made extensive investigations of the quality of the science, the UK standing and abilities in the field, and the resources needed. It was found that the Large Hadron Collider programme is scientifically of the highest importance, and that the UK has a very high international reputation in the field, both for the quality of its science, and for its technical developments. The electronics group at CCLRC stands out as a prime resource in the field. The July 1994 POST report, "The Nature of Matter?—International Collaboration in Particle Physics" provides a useful reference on this. The (draft) National Audit Office consultative document proposes quality measures relevant to the field on which the UK scores highly. There is therefore no doubt that, judged by the parameters of investigative science, the LHC acitivity is vital, and the UK is of the calibre, both intellectually and technically, to make very good use of it.

The UK can justly take pride in the achievements of CERN. Our investment there over the years has led to notable discoveries, and to a shift in the scientific centre of gravity across the Atlantic towards us. The SPS accelerator which started this process was built under a British Director-General. The LHC is to be built under a UK Director-General and a UK Project leader.

The LHC needs very advanced technology, both for the accelerator and the detectors. UK universities and CCLRC established an early lead in detector technology, including ultra-high bandwidth data communications, and radiation-resistant technology. In some cases the technology is well in advance of the market, but there are areas, in sensors for example, where there is an excellent match to Technology Foresight.

PPARC produces a modest number of PhDs compared to some other councils: it wishes to increase the number. However, the training environment of "Big Science" in international collaboration and with high technology fosters the skills of competitiveness and leadership which are sought after by employers.

PPARC supported the panel recommendations I presented that the expenditure on LHC related work in the UK should be capped at 75 per cent of the resource available for investment in UK Domestic Particle Physics. The LHC is the core activity for the future, but the diversity represented by other activities (chiefly underground searches for cosmic dark matter, neutrinos, comparison of matter and antimatter) adds considerably to the vigour and health of the field in the UK. In the period leading up to the LHC turn-on (2004), it is our policy to maximise the return from our present investments in equipment at CERN (LEP, till 1999), and DESY, Hamburg (beyond 2000.)

CERN is developing into the dominant world centre for Particle Physics—witness the recent gift of 5bn Yen by Japan. It makes no sense to duplcate facilities on this scale. A system of inter-regional exchange has developed. UK scientists benefit from the use of facilities in Canada and the USA, and in turn scientist from these countries make use of CERN. As a developed European state without domestic facilities to offer to US groups the UK must be a member of CERN in order to gain from such arrangements. Following the OECD Megascience Forum meetings, where the UK has pushed strongly the idea of the balancing of projects over a range of disciplines, our commitment to CERN is now a factor in our access to future facilities in other fields.

Construction of the LHC detectors requires the UK to make commitment for expenditure up to 2004 for construction, and to make provision for operation beyond there. Yet government cash planning extends only a few years ahead. Given a constant real-terms domestic budget we are able to make coherent provision for UK exploitation of the LHC, but at a level a good deal below that corresponding to our contribution to CERN costs. The UK Domestic Particle Physics programme has been underfunded in recent years. It has therefore been our policy for some time that the costs of the UK CERN contribution and the domestic programme should be re-balanced in favour of the domestic programme. During the latter years of the SERC, a modest re-balancing took place, to the benefit of Particle Physics within the UK.

It was disappointing therefore that, while the international negotiations leading up to the LHC approval, (conducted by OST) delivered notional savings to the UK by future underindexation for inflation after 1997, no immediate savings were returned to the UK, although UK negotiating support was a factor in Germany's obtaining an extension of immediate financial relief to them.

The LHC is to be built out of a CERN budget which is declining in real terms. We have every reason for confidence that the management can deliver. The previous (LEP) construction was delivered on time out of a constant budget. This framework should be sufficient to stabilise the UK budgetary position in normal times. In fact two factors have led to a great short term difficulty—the rise in the value of the Swiss Franc relative to all currencies, and the fall in value of the Pound relative to all currencies. (The CERN budgetary rules provide relief for downward movement of the Pound against other currencies except the Deutsche Mark.)

As a result, and paradoxically, a declining CERN budget has led over the last two years to a rapid increase in our Sterling contribution, and this is putting the PPARC budget under great strain. (A similar but less dramatic story affects ESA.) The government is content to let the value of the Pound fall for other policy reasons: but some years ago it was urging us strongly, and correctly, that the future of large scientific projects lay in international collaboration. There is an urgent need to prevent the science being blown of course by a collision between these two policies.

Both the Particle Physics and the Astronomy committees have presented forward plans to PPARC. Unless the problem of the declining Pound can be addressed, for example by securing a lower CERN contribution, (which is not impossible at this point in the LHC process,) or by new arrangements for handling the impact within the UK of Sterling's decline; then the UK will certainly have to abandon or curtail drastically high quality and productive science. There is equally a danger of destructive competition breaking out between two branches of science in which the UK performs very well. At present the UK is well placed scientifically, technically and in terms of project management to make excellent use of CERN. But the dangerous erosion of domestic funding can put this in jeopardy.

I would be happy to give oral evidence, should you wish it.

Letter to the Clerk of the Committee from Dr M G Green (4.12.95)

1. From January 1992 to August 1995 I was Chair of the Particle Physics Experiments Selection Panel, the peer review body of PPARC responsible for considering proposals for experiments in Particle Physics and for the regular monitoring of approved experiments. I know the UK scientific programme in this field very well and the scientists involved in the universities, at the Rutherford Appleton Laboratory and at the PPARC headquarters in Swindon.

2. During my term of office PPARC came into being and almost immediately set up a panel, of which I was a member, to advise on the UK's future programme in the light of the strong move forward by CERN to build the Large Hadron Collider. The scientific case for the LHC was already universally accepted and even emphasised by the demise of the SSC in the US. The panel had no doubt that if the UK is to continue to participate in particle physics it can only be through CERN and the LHC. Indeed it proposed that up to 75 per cent of the resources available for expenditure on experiments should be committed to those at the LHC even though this will restrict the breadth of the UK's programme and leave us unable to participate in many important areas.

3. We looked carefully at the resources available in the UK and those needed to exploit the LHC at a level which made proper use of the UK's undoubted expertise. We found that the UK could participate at a reasonable level if funding were maintained in real terms and if the savings negotiated by the UK government as part of the LHC agreement were made available for domestic spend. However if the available domestic moneys continue to decrease in real terms at the same rate as in recent years (approximately 40 per cent since the Kendrew Report 10 years ago) then the UK will not be able to participate at a level which gives adequate return for our CERN subscription. A particular problem of recent years has been the increasing strength of the Swiss franc and its impact on the subscription.

4. PPARC responded to our report positively. It accepted fully the scientific case for the UK's involvement in the LHC and determined to find the resources required in so far as it is able. In particular it reiterated the SERC policy of "redressing the balance" between the CERN subscription and domestic expenditure by setting a long-term target that PPARC international subscriptions should be no greater than 50 per cent of its budget. The UK particle physics community fully accepts that this is the right way forward.

5. The above method by which PPARC determined its priorities in particle physics was, to my mind, enormously successful. Members of the Council and the officers of PPARC deserve recognition for their approach and subsequent response.

6. The areas of technical expertise in UK particle physics are well known and internationally respected. They include particle tracking technology (particularly in the use of semiconductor detectors), fast electronics and triggering, optoelectronics, calorimetry, magnet design, data acquisition. It is in these areas of strength that the UK is contributing to the LHC experiments. There is absolutely no doubt that we can contribute fully to the experiments and exploit them properly; indeed we are already leading much of the prepatory work in the above areas. The opportunities for British industry are legion.

7. As a university physicist who frequently visits schools to talk to sixth-formers and teachers I would argue strongly for the continued involvement of the UK in particle physics. The interest shown in the work of CERN as evidenced by questions during my visits is extremely high. There is absolutely no doubt that particle physics captures the imagination of both school pupils and the general public and it is frequently influential in leading young people towards a career in science. It is highly significant that many examination boards have introduced particle physics into their A-level physics syllabus in recent years.

Letter to the Clerk of the Committee Professor A D Martin and Professor W J Sterling (6.12.95)

In our opinion it is essential that the UK maintains an active role in fundamental research in Particle Physics. Traditionally, British physicists have been at the forefront in pioneering developments in this important field. From our experience, it is clear that Particle Physics is one of the major reasons why young people are attracted to study science at university.

The Large Hadron Collider (LHC) is the natural way forward to achieve a deeper understanding of the laws of nature. In particular, it is the unique way to explore the "origin of mass", which is the outstanding question at present. The LHC may expose the existence of new particles such as the Higgs boson or supersymmetric particles, but in any event it is guaranteed to significantly advance our understanding of the fundamental particles and their interactions. Utilization of the existing collider infastructure for the construction of the LHC opens up an entirely new energy regime at remarkably modest cost, keeping Europe firmly at the forefront of Particle Physics research.

With their experience at CERN, DESY and other world laboratories, UK scientists are already playing a major role in the development of the large scale experiments at the LHC. Their expertise is proving crucial in overcoming the formidable technological challenges presented by the design and construction of such intricate and complex particle detectors. The ability to continue to contribute so effectively in this way requires domestic financial support commensurate with the investment in CERN. Such support is at present at a bare minimum.

European Particle Physics is a model of international collaboration. We believe that despite the current uncertain economic climate it is exceptionally well managed and is kept, via the peer review system, well focused towards the most pressing scientific objectives.

Considering the short-term uncertainties of government funding of basic research, we believe that PPARC has done a remarkable job in a difficult environment. The peer review allocation of funds has allowed a good balance of the distribution of the extremely limited resources to be maintained. It is, however, unfortunate that these funds are barely sufficient to support the large scale experiments at CERN and DESY, and do not allow the UK to have more participation in a broader portfolio of (non-accelerator) experiments, unlike our European partners.

Letter to the Clerk of the Committee from Professor Peter Bussey, University of Glasgow (7.12.95)

In its Press Notice, the Select Committee enquiring into the Particle Physics and Astronomy Research Council has invited comments on aspects of the latter's work. As Senior Lecturer in Physics at Glasgow University, I should like to submit the following to the Committee's attention.

Since the early 1980's I have taken part in particle physics experiments at DESY, Hamburg, where I currently work on the ZEUS experiment. The creation of PPARC, in my view, was a decisive step forward in establishing an efficient body with a well defined remit in administering areas of "big science" such as my own. Although I cannot comment on the Astronomy side, I have found that the Particle Physics organistion functions well and allows decisions to be made in an appropriate manner on suitable timescales. As a recent member of the Particle Physics Experiments Selection Panel, I can vouch for the overall sensible style of decision-taking. The fact that the recommendations are made by one's peers gives physicists confidence that the procedure is taking place on a rational and well informed basis, and there are rarely any serious complaints, even when less funding is granted than a proposal perhaps deserves. The structure of PPARC, in short, seems excellently suited to the carrying out of its responsibilities in this area.

For UK scientists to participate fully in very large collaborations, it is necessary that these be well organised, and with an emphasis on active participation by those not resident at the laboratory centre (e.g. CERN). I believe that due attention is being given to these matters, but the Committee might do well to give some stress to them in its report. It is particularly essential that a major international collaboration have an effective managerial structure together with an appropriate constitution. There are various ways in which these requirements are successfully implemented in existing collaborations.

Clearly, I consider it of the utmost importance that the UK participation in "big science" is fully maintained, which especially means fundamental physics and astronomy. Subjects such as these are absolutely central in supporting a scientific ethos in our society, from which all the sciences benefit. A lack of this would undermine the motivating spirit behind all science.

Memorandum submitted by Dr John Garvey, University of Birmingham (7.12.95)

How does or should PPARC determine its funding policy?

Particle Physics research receives about one half of the PPARC budget, amounting to about £95 million for the financial year 1995–96. This level of support is derived quite fairly as a continuation of the level enjoyed before the White Paper, when the funding was determined by the SERC through the Nuclear Physics Board.

The majority of this support goes into paying the CERN subscription, about £60 million in 1994, £66 milion in 1995 and predicted to be £75 million in 1996. It is already evident from these three years alone that the cost of CERN is rising at a very high rate in pounds sterling, and this is due not to increased cost at CERN in Swiss francs but rather a monotonically decreasing exchange rate of the pound versus the Swiss franc.

In the White Paper a promise was made to protect science against fluctuations in the cost of international subscriptions caused by currency fluctuations. The £6 million increase in the CERN subscription in 1995 was indeed paid by non-PPARC funds. However, the resources for this came from a top slice applied to all Research Council funding made by the Director General of Research Councils. The net effect was that the increase came from PPARC funds, and seems not to be in the spirit of the promises made in the White Paper.

The funds remaining after the payment of the CERN subscription are needed to fund the "domestic programme". This may appear to be a parallel activity to funding CERN but it is not. The CERN subscription allows UK physicists access to the facilities there, principally the particle accelerators. However resources to mount experiments to make full use of these facilities, and including the manpower required, come out of the "domestic programme", and account for about two thirds of that programme. At present levels of PPARC funding it is clear that 10 per cent increase in the CERN subscription represents at 20 per cent cut in the "domestic programme". If the CERN contribution in pounds continues to rise without any real compensation, there will soon be no funds left for UK physicists to mount experiments and exploit the CERN facilities which we are paying for.

This is clearly an unsatisfactory situation. CERN is undoubtedly the world's foremost particle physics laboratory and some of the credit for this must go to the contribution made by UK engineers and physicists. It is our laboratory and we are proud of it. As a European venture it is efficient and very successful, and is in many ways a perfect example of how collaboration can be made to work in a very challenging environment. These remarks are non-controversial. To be a member of such an organisation, but be unable to exploit the benefits of membership fully, makes no sense for UK physicists or UK industry.

Those who established CERN in Geneva in 1954 could not have guessed at the rapid rise in the value of the Swiss franc against all European currencies. Had CERN been established in France, where geographically most of it lies, the distortion caused by exchange rates would not have been anything like as severe.

How does all this bear on the funding priorities of PPARC? Sufficient funds must be made available to exploit the benefits of our CERN membership. Exploitation can only be maximised by being involved in all facets of the high technology activities at CERN. The purpose of the laboratory is to probe and understand the structure of matter of which we are all made. This is a reasonable and hopefully affordable aim for a civilised society, and is always stated clearly as the principal goal of CERN. However pursuit of this goal requires the application of the most advanced technology, and even the invention of new technologies. Experiments on the Large Hadron Collider (LHC), are already demanding technology advances in eg particle detectors, optical data transmission, custom designed silicon chips, superconducting magnets, and advanced super computing. UK engineers and physicists are contributing to the solutions of all these high technology problems, by involving UK industry in the search for solutions. The components for the particle physics experiments of the next century, which are being designed now, must come from industry. A compromise will be established between the level of technology particle physicists require, and what industry considers a sensible market demand. The pressure from the physicists can only push this compromise in a more ambitious direction, and this can lead to significantly faster technological evolution. This additional push towards more challenging solutions is of course only a small pressure, which is part of a greater whole coming from other market considerations, but it is a finite one.

In parallel with this, the requirement to come up with a solution to a problem in the pure science in which particle physicists are active, can occasionally produce a completely new unexpected technology, for instance super conducting magnets, cathode ray tubes, and portable high precision particle detectors used in many industrial applications.

If UK particle physicists are not involved in defining the instruments to install on experiments, they cannot initiate the potentially productive involvement of UK industry. More significantly for them they cannot influence to the same extent the direction of the experimental programme. The result of this will be a reduction in interest in the subject and in the overall level of intellectual activity in the UK.

How important is it that the UK continues to participate in "big science" projects such as LHC?

The pursuit of scientific research is an important activity for any civilised society. On a purely cultural level it stimulates the intellect of the people actively engaged in it and as a result adds to the overall intellectual level of the society. Most applied research leads to some spin-off which is related to the primary aim of the research. Pure research can contribute to developments in an unexpected direction, often involving significant advances, which helps society in a more tangible way.

Big science is trying to answer very simple questions. When working at the limits of smallness as in particle physics, or the limits of distance and time as in astronomy, these questions although simple to formulate, are difficult to address and require the design and manufacture of very expensive instruments. These instruments are expensive because they demand the application or even invention of the most advanced technologies in mechanical and electronic engineering. They require engineers and scientists who are able to make evaluations of what is required, and have the ability to involve industry in challenging R and D towards its provision. This plays a small but finite part in the continuing evolution of industrial skills required for industrial competition on a world level.

Big science nowadays is pursued by international collaboration. CERN is a good example of a successful European collaboration. Productive interactions between visiting scientists and engineers from all the member states of CERN are occurring every day. At an intellectual level these interactions have a positive effect on the intellectual level of activity in UK universities and research laboratories. At an industrial level, the capabilities of the different member states industries are on display, and result in a significant amount of knowledge transfer. Such a forum as CERN is not just a market place for trading ideas of basic research, but also for the perception of what has been achieved and is achievable by industry in the member states. These technologies are normally at the leading edge of industrial research, in say electronic engineering and computing, as successful pursuit of the science is often limited by technical limitations. The magnitude of such cross fertilisation is difficult to judge, but the technical level at which it is occurring is not.

Big science must be funded at a level which allows visible progress to be made in solving the basic problems which it is addressing. Only in this way will a stimulated body of scientists be attracted into pursuing it. The benefits which may come in other unexpected fields are then a real possibility.

Are UK scientists able to fully exploit this type of collaborative facility?

Successful exploitation of the facilities at CERN depend critically on the level of resources which are available. The CERN subscription pays for access to the facilities at CERN. These facilities are the accelerators and the beams which they produce. Building and mounting of experiments designed to use these beams to address questions in particle physics must be separately funded. A low level of funding leads to a low level of involvement of UK scientists and engineers, and therefore a low level of exploitation by UK scientists and engineers. This is not a linear effect. Low involvement leads to reduced influence and a rapid decline in the benefits of being part of the organisation.

How does one measure the level of involvement and how does one judge whether it is efficient or not? There seem to be many facets to this question.

A presence at CERN is obviously a first essential requirement. This is easier for scientists and engineers from France and Italy as the distance for many of them is not so great and the journey does not require an expensive flight. France has gone as far as building a particle physics laboratory at Annecy, a distance of about 50 kilometres from CERN. Two categories of presence are required here, long-term and short-term. While experiments are being assembled and running there is a need to have physicists and engineers in residence. At other times in the life of an experiment fewer residents are needed. However then the possibility of frequent short visits is vital to ensure real involvement in the conception and design of experiments, and later in the evaluation of the physics results.

The money required to sustain this presence is small as a fraction of the UK overall budget. However it is a vulnerable part of that budget, as it can be adjusted quickly and easily to compensate for rapid changes in available funding. An increase in the sterling cost of the CERN subscription this year, 1995, has resulted in a very serious reduction in the available travel money, with severe consequences to the UK presence in CERN. This occurred because travel was one commitment which could be reduced quickly.

A second very important requirement for effective exploitation is the availability of cash resources to support the experimental programme. The UK pays at present about 14 per cent of the cost of CERN. To say that a logical level of involvement in the building of experiments is also 14 per cent is oversimplifying the whole situation, but it does give a guide to the level that is required. UK physicists and engineers are highly respected at CERN. Our functionality, and the highly effective manpower resources which we possess in the UK, make us welcome collaborators in most experiments. This has allowed us to be part of international collaborations while being unable to pay our full pro-rata share of the cost. This has been the basis of an acceptable balance in the past. Over recent years as the support for the "domestic programme" has fallen in pounds, the imbalance in financial contribution between the UK and other member states has become more severe. Not only does it cause resentment in the collaboration, but more importantly it reduces the influence of UK scientists in the way the technical challenges are solved and where they are solved. Maximum benefit to UK science and industry comes when specification, design and construction of experiments is done here. This more difficult to engineer when it is clear that the UK participants are unable to contribute what is regarded as a fair share of the cost.

It is very clear that up to the present UK scientists have fully exploited the facilities at CERN, and are valued members of the CERN experiments. A critical time is coming. This will be during the design and construction of the experiments to run on LHC, when significant resources will be required over the period up to the year 2004. The rising cost of the CERN subscription in pounds could make this funding very difficult in the UK.

HOW SHOULD MAJOR INTERNATIONAL PROJECTS BEST BE MANAGED AND FUNDED?

The management of particle physics experiments at CERN is very successful. Up to the present the control of costs has been very good with the majority of major projects coming in on budget and working. CERN has a budget agreed in Swiss francs every year and has a fairly stable and well-defined level of support from the member states. All the CERN accelerators which have been built over the years have been projects managed by CERN personnel and they have had an impressive record of successful completion both in time and performance.

The experiments which are mounted at CERN usually involve some CERN staff but the management is done by elected spokespersons from the member states. Over the years experiments have grown in size and complexity, and the spokespersons have been supported by full-time technical co-ordinators. This was the pattern for the Lep experiments and will be one used for the LHC experiments.

Experiment building cannot be embarked upon without guaranteed resources and all large experiments have a Memorandum of Understanding which is agreed by the funding bodies of the member states involved in the experiment. For the LHC experiments the build period is from now to 2004. Significant long-term commitments have therefore to be made to assure the successful completion of the experiment building. This was the procedure for the Lep experiments and worked extremely well. The contributions to experiments are calculated in the currency of the member state involved, and so are not affected by exchange rate fluctuations relative to the Swiss franc.

To guarantee that the resources for experiment building are protected against exchange fluctuations where the total PPARC particle physics budget is fixed in pounds, a different approach may have to be adopted to the payment of the CERN subscription. A present this in effect comes off the PPARC particle physics budget. From experience over the last few years this represents a serious problem, and may be the most serious one facing particle physics in the next few years. There seem to be two possible solutions to the problem.

Firstly the responsibility for paying the CERN subscription could be decoupled from PPARC, and paid directly by the Treasury. This is already the method used in many of the CERN member states. Secondly the

CERN subscription could be fixed in the currency of the member states for each member state. This could, for instance, be fixed for the UK at the 1995 level of £66 million, and corrected for UK inflation in subsequent years. At the present level of total PPARC particle physics funding, this would leave a total of £29 million per annum to pay for experiment building and exploitation. This solution would obviously make life more difficult for the CERN management, but would ensure the continuation of UK involvement in experiments in the scenario of a fixed PPARC particle physics budget in pounds.

How appropriate is PPARC's structure for its research profile?

The management structure of PPARC is different from that which existed under the SERC. The chairmen of the Nuclear Physics Board and the Astronomy Board sat on the SERC and represented the interests of their prospective communities. They presented the scientific programme, which had emerged from lower level committees where it had been peered reviewed, and argued for support.

This is not the way the system operates under PPARC. The chairmen of the subject committees, the Particle Physics Committee and the Astronomy Committee, do not sit on PPARC. The vital direct link with the committees lower down and their peer review function, has been replaced by an indirect link. The scientists on PPARC are there ad hominem, and are not supposed to speak in support of their particular subject. This seems to me to be a regrettable development which removes the direct line of communication.

On the details of the precise portfolio I have mixed feelings. Both the astronomers and the particle physicists have significant international commitments. If increases in international subscriptions are paid outside the PPARC allocation then the present mixture of activities may be acceptable. If not, which in reality was the case in 1995, then the fixed total resources available in PPARC do not allow any flexibility, and inevitably any scientific choice. Involvement in astronomy and particle physics based activities, on a reducing residual budget will decrease.

The level of PPARC support is decided by the committee above PPARC, where active scientists are not present, and scientific debate between different scientific disciplines does not take place. The broader scientific forum seems to have been lost in the new organisation which has come into place after the White Paper.

Memorandum submitted by Professor R J Cashmore, University of Oxford (8.12.95)

I write as Head of the Particle Physics Department, University of Oxford, a former Chairman of the Particle Physics Committee of SERC, Principal Author of Particle Physics 2000—"A Strategy for Particle Physics in the Next Century" and as a member of selection panels and advisory bodies throughout the world. I will address the main issues raised in the Press Notice from the Select Committee.

1. PPARC Long Term Policy and Funding Priorities

Clearly the Council must determine it's future science policy on the basis of the quality of science proposed and the quality of the scientists proposing to perform it. In this Research Council this is mainly "blue skies research". However one should not underestimate the degree of technical innovation that is required in these complicated experimental programmes or the amount of contact within industry in the United Kingdom and in Europe that is required to produce the experimental facilities. There have been, there are, and there will be substantial technical spinoffs associated with research performed by the Council, probably the best known current example being the World Wide Web software developed at CERN by the Particle Physics Community.

The work of PPARC is by nature, long term, and the issues that are being addressed require sophisticated equipment, equipment that is in general impossible for a single country to provide. This has resulted in the healthy development of a truly international research environment in Particle Physics and to a lesser extent Astronomy. In the case of Particle Physics this is a direct result of the responsibility of the scientists involved, who realise that the only way of achieving certain goals is indeed by international collaboration such that the costs to any individual community are reduced. In this situation it is important that PPARC grabs the opportunity and makes a good job of exploiting the research environment so carefully prepared.

As research is long term, PPARC is particularly susceptible to the vagaries of short term policy changes and the state of the United Kingdom economy and currency. For PPARC to conduct sensible scientific research programmes in these circumstances I believe it is important that the Government rethinks its contributions to international activities. Once it has made a commitment to join such activities, then the funds required should be provided in the same manner as for other international obligations. This is not an open ended commitment—all such projects have carefully considered financing and management schemes which can be revised. On the other hand the funds necessary to exploit these international facilities should be subject to the normal regime that occurs for funding research inside the United Kingdom. I cannot impress upon you how important such a policy will be for sensible continuation of the research areas of PPARC.

2. The Importance of "Big Science" Projects

Particle Physics is addressing some of the great scientific questions of our time. Questions that are major by any scientist's standards. It is these great questions that excite and attract young people into science. These are just the people that one requires in our future society, which is going to become increasingly more dependent on science and technology whether we like it or not (and I personally believe that the quality of life will continue to be enhanced by such developments). We all have many, many examples of cases where students have been attracted by the questions of Particle Physics then end up finding that other areas of science are both exciting and more immediately valuable to the community at large. Restricting our ability to address these big scientific questions I believe imperils our ability to recruit a cohort of young scientists on which the country's future will depend. Furthermore one should not underestimate the pleasure that understanding the origin of matter or indeed the origin of the universe brings to many of the public. They enjoy listening to it, they enjoy attending seminars on it and they are even willing to pay for weekend courses on it.

3. Exploiting Collaborative Facilities

At present United Kingdom Particle Physicists have a good standing in the international community and this has been recognised by many recent interviews (eg those of Kendrew and Ledwirth) They are able to exploit the facilities particularly at CERN, but also at DESY in Hamburg, and are respected members of the collaborations. Resources are tight but their ingenuity, efficiency and organisation keep them in this position. Unfortunately, the current funding of the domestic programme is being reduced, because of the increasing international subscriptions which are beyond the direct control of the scientists. This makes this exploitation progressively more difficult to sustain. As I indicated earlier, this is the most serious question that faces PPARC, but it is really the Government which needs to face this issue and ensure that it confidently supports such commitments to international activities. I would expect it to want to see the investment fully exploited.

Particle Physicists in the United Kingdom realised a long time ago that they could not cover all areas of the science by themselves and that the best way of proceeding was to enter into constructive collaboration with other countries and groups. This has been done very successfully both at the level of building the accelerator facilities (most conspicuously), but also at the level of constructing the experiments which exploit these accelerator facilities. There can be no doubt about this. In the last ten years there have been at least three major external reviews of United Kingdom Particle Physics and of CERN. They all came out with ringing support for the quality of the science and the scientists performing it as well as recognising the success of their collaborations. Such reviews are to be welcomed. Along with the good they often turn up things that can be improved, and these reviews were exceptions. Particle Physics in the United Kingdom and Europe has benefitted.

Indeed within PPARC similar benefits would flow if the whole of the Astronomy and Astrophysics programmes were subjected to similar extensive reviews investigating not only the quality but the efficiency, cost effectiveness and the extent of collaboration that exists and might be desirable. International collaboration is the way to proceed with this science. Particle physicists certainly exploit this approach effectively and there is no reason to doubt that Astronomers would do as well.

4. The Management and Funding of Major International Projects

I think history has shown that the best way of proceeding is that the lead be taken by a regional group as in the case of the LHC, where the motivation was due to the member states of CERN. Increased funding for a project can then be obtained by other countries supporting this initiative. Clearly the management structure has to be defined and a clear funding basis agreed at the outset. There are many large scientific projects and therefore plenty of scope for different regions in the world to take the lead in their construction and implementation. Any other approach would tend to lead to long delays in achieving agreements and a consequent sapping of the scientific momentum.

In determining the support expected from other countries to a project, it is important to bear in mind the broader picture of science and the facilities in which they have taken or will be taking the lead. As more sophisticated equipment and facilities are required, this sort of international collaboration will increase throughout science and it would be beneficial if a "grand" view was encouraged.

5. PPARC Structure

PPARC is mainly addressing fundamental scientific issues which are at the edge of our knowledge and understanding.

In this environment it is not appropriate to "pick winners" or determine the course of research on the considerations of a single person as was conceived, I believe, in the creation of Chief Executives. This may be appropriate in other research councils but has little merit in PPARC. What is required are clear lines of responsibility from the Council to the community and vice versa. Chairmen of major science sub-committees should be present at council to argue their case and position as well as listen to that of others. This does not happen at present and should be changed, thus allowing a sensible debate over the priorities of the programme and resetting these where appropriate.

Particle Physics has been very efficient and effective in the use of public funds. The cost of administration of it's programme is comparatively small. This is due to two major factors—spokesmen for consortia of university groups determine the expenditure in individual projects (ensuring there is no wastage at the margins) and the infrastructure in each university group is supported by a rolling grant (reviewed on a regular basis). PPARC thus has few particle physics "items" to administer.

It is possible that a similar approach would lead to increased efficiency in the astronomy and astrophysics area, where at present there are a plethora of grants to be administered. Releasing resources would mean that more support could be devoted to the science. Such considerations are, moreover, essential if the Council is forced to face budget reductions.

In summary particle physics addresses important scientific issues and is a conspicuous example of successful international collaboration. This has been brought about by responsible scientists wishing to minimise the cost to the taxpayer and yet provide the scientific answers. Astronomy and astrophysics are following in the same footsteps and should they be successful even better science will be within their reach. Continued, willing, support for PPARC will ensure good and exciting science, in which I hope the Select Committee can take a great deal of pleasure.

Letter to the Clerk of the Committee from Dr John Baruch, University of Bradford (7.12.95)

May I contribute to the inquiry into the Particle Physics and Astronomy Research Council. In my opinion PPARC is performing an excellent job with very limited resources. This note is concerned with the hidden resources of PPARC science that Government neither recognises nor exploits. The nation does not appreciate fully how to reap the benefits of its investment in PPARC. It fails to understand the value of the community it has created through PPARC and the potential this community has to contribute to wealth creation. A broader discussion of these issues is presented in the enclosed paper "In Search of Passion" (*not printed*), published in the May issue of Science in Parliament. The ideas are sumarised below.

There is a close parallel between the success of scientists in the PPARC arena and the success of small to medium sized companies (SMEs). I believe that the benefits of recognising, encouraging and funding links between them will provide excellent returns.

An important component of both their successes is the exploitation of new technologies. For SMEs their innovative exploitation of new technologies is the basis of new products, manufacturing methods and services which give them competitive advantage in there markets. For scientists in the PPARC arena it is the innovative exploitation of new technologies that is the basis of finding new solutions to problems or of creating new istruments with which to attack the problem. This creativity gives them the edge to maintain a position of world class for the UK with minimal funds. It is generally recognised that the growth of SMEs contributes disproportionately to job creation when compared with larger companies. Better links between academia and SMEs would I believe greatly benefit both.

The Technology Foresight exercise recognised that the Universities make Britain attractive to large companies for one reason alone and that is the quality of the personnel they produce. In the areas of IT, electronics and communications, research results are of little interest to them, the human results are. The PPARC subject area has an excellent record of developing, attracting and inspiring the very best minds. It is recognised that it is the minds that make the difference not the details of their studies.

In the areas covered by PPARC, British scientists are arguably the best in the world at innovation. Britain's failure to recognise this goldmine is a loss we cannot easily afford.

Letter to the Clerk of the Committee from Dr B Foster, University of Bristol (8.12.95)

I have been involved in the planning and management of particle physics in the UK based abroad over the last 10 years. I am currently a member of PPARC's Particle Physics Committee (PPC) and will become chairman on 1 January 1996.

Particle Physics attempts to understand the basic forces and particles which have governed the evolution of the universe since the Big Bang, and which continue to govern the universe today. Since the Big Bang occurred at unimaginably high temperature and energy, it is essential to particle physics to recreate these conditions as far as is practicable in a controlled way by colliding very energetic particles at large particle accelerators. The more energetic the collisions, the more complex and large the experimental apparatus required to examine their products and unravel their secrets. Although the energy of collisions has been increased over the last 30 years by a factor of more than 100, the budget of CERN, where many of the most important discoveries have been made, is smaller in real terms now than it was then. The budget in the UK has declined substantially over the same period.

I believe that it is essential for the UK to continue to be involved in large "Big science" projects such as LHC. Whatever the actual mechanism which gives particles mass, be it the famous "Higgs mechanism", or something more complex, it will be revealed at the LHC. Furthermore, the increase of the available energy at LHC by almost a factor 10 is, if experience from the past is any guide, almost sure to reveal phenomena which we have not even imagined. It is accepted throughout the world that LHC is the most important particle physics facility for the next decades. Every country active in particle physics will be taking part in LHC experiments. Quite apart from the sheer intellectual challenge of searching for the fundamental forces and particles of Nature, it is well documented that particle physics and astronomy are the major factors in attracting young people into the study of physics. Very few of these end up as professional particle physicists; the great majority go into other branches of physics, science, industry, financial services and commerce. I would therefore contend that the logical sequence: LHC is the most important project for the future of particle physics; a vibrant particle physics activity attracts the best young people into science; and these young people go on to permeate the UK economy forms the core of my answer to the committee's question. Most importantly however, we do particle physics because we want to find out how the universe works, and the LHC is the best device to help us to do this.

Although LHC is the first priority in particle physics, it is not the only priority. LHC can be likened to a great observatory with telescopes capable of observing a large part of the electromagnetic spectrum. However, there are many other wavelengths and many other experiments. Particle physics needs some breadth as well as depth, and we must be involved in some at least of the very large range of first-class particle physics experiments going on in the world. Without this, the very long lead time between experiments would mean that the particle physics community would not be able to sustain itself; as an example, if the UK were only involved in the LHC, there would be at least five years between the end of experimentation at LEP when there would be no UK experiment taking data at CERN. The question of the necessary breadth of the particle physics programme was addressed in the "Particle Physics 2000" document published by SERC which will be available to the committee. The inevitable long gestation of LHC experiments emphasizes that artificial delays caused by funding shortages or mismatches are very serious in that they prolong what is already a very long process. This makes it difficult to motivate particularly young postdoctoral scientists whose contracts will end before experimentation begins.

The committee asks if researchers are able fully to utilise the large international facilities in the PPARC remit. The answer is yes, with the provisos that this is becoming steadily more difficult owing to increasing financial difficulties and increasing teaching and administration duties for university-based researchers. I will return to the cause of the increasing financial difficulties at the end of this submission. Their result is to restrict the influence and activity of UK researchers in several ways. It is uncontentious and widely documented (see for instance the letter sent recently after a visitation of the UK by the Chairman of the European Committee for Future Accelerators, copy enclosed) that UK particle physics have a very high reputation in the world of particle physics, both as designers and builders of complex apparatus, particularly electronics, and as innovative and productive analysers of data. However, over the past few years resources have shrunk to such an extent that UK physicists have only been able to contribute well below the pro rata contribution of other European colleagues to experiments. A recent typical example, the ZEUS experiment at DESY, shows the UK contributing to the experiment construction at about 55 per cent of other countries. While the high reputation of UK physicists has to a large extent mitigated the inevitable loss of influence concomitant on this low contribution, it would be unrealistic to expect that this situation can continue indefinitely. Furthermore, the nature of particle physics is that very large and technologically challenging apparatus with performance at the cutting edge of what is possible needs to be developed continually. The lack of resources available to UK physicists restricts their ability to fulfil their potential in these developments which are often important to industry as well as particle physics.

A further difficulty is the increasing level of teaching and administration effort required of university staff. Since the operation of these large experiments is extremely complex and time-consuming and requires constant attention if they are to perform at their optimum, it is essential for particle physicists to spend substantial amounts of time at the site of their experiments, usually either at CERN in Geneva or DESY in Hamburg. Heavy teaching loads combined with the administrative pressure due to the ever-increasing number of reviews and investigations to which our university system is subject mean that travel to the experiments becomes increasingly difficult, particularly in term time. Nevertheless, by travelling and working over weekends, UK physicists have succeeded, up to now in fully utilising the large international facilities in particle physics, as evinced by the esteem with which they are regarded and the large number of responsible positions in experiments which they hold.

Thirdly the committee asks how international projects should be managed. I believe there is little or nothing wrong with how this is currently done in particle physics. Founded in the ruins of postwar Europe, CERN has proved an examplar of what can be achieved by European collaboration, and has inspired many emulators both in science and in other fields. Its provides a means to pursue excellent science beyond the means of any member state while being responsive to the concerns of both member state governments and its user community. Its functioning has been the subject of many international reviews and enquiries, whose findings have been overwhelmingly positive and whose suggestions for improvement have been adopted. Despite the fact that CERN's budget has fallen in real terms, it has continued to produce world-beating science. There is little or no dissent to the view that for at least the last 10 years the US has lost the leadership in particle physics to CERN and Europe, one of the few scientific fields in which this can be attested.

The management of the UK part of these international projects has been even more widely reviewed and investigated. UK particle physics has always had clear strategic goals and a small and effective management structure to carry these out. Strategy is fixed by a peer review committee, the Particle Physics Committee, and the day to day management of the programme centred at RAL. Although this has meant that some grant money earmarked for the capital build of experiments has not passed through university books, which has probably led to some loss in university support, the flexibility to respond to underspends and overspends in different projects has meant that the ever decreasing funds available to build and operate particle physics experiments have been used optimally. Inside the universities, all experimental groups are funded by rolling grants, which are rigorously peer-reviewed but very simple to administer, and which give the stability necessary for a subject in which the design, building, running and analysis of an experiment take at least a decade.

Finally the committee asks about the structure of PPARC and how suited it is for its task. In general I believe it has been a great success and operates well. This is particularly clear in comparison to EPSRC, whose user community, particularly in physics, appears to be extremely dissatisfied. The very well focused nature of PPARC, its concentration on two disciplines which are heavily internationalised and which have intimate connections over a broad range of their activities has made for an efficient and well-managed council. Within PPARC there are of course very great differences between the ways the astronomy and particle physics communities run their activities; for example, the particle physics programme is managed with many fewer staff.

I believe that there is one area in which the structure of PPARC could be improved. The PPARC Council itself consists of purely *ad-hominem* appointments. Although this has some strengths, it does mean that the Council can at times be somewhat ill-informed about the aims and priorities of the communities it serves. This would be greatly ameliorated if the chairs of the major subject committee, in astronomy and particle physics respectively, were members of Council, as was the practice in the old SERC. They could act as advocates for their subjects, leaving the remaining members of Council free to take a more detached and strategic view. In the current structure, there is an inevitable tendency for the astronomers and particle physicists on Council to become overtly partisan. This tendency is only likely to increase if resources available to PPARC continue to be squeezed. There are already worrying signs that this is beginning to happen.

In conclusion I must draw to the committee's attention what I believe is the greatest concern both to particle physics and PPARC today. The fluctuations in the international subscriptions to CERN and ESA make rational planning of long term projects very difficult. This is of particular concern for CERN, where the subscription is paid in Swiss Francs, against which the pound has recently been extremely weak. Although there are mechanisms to correct for this in the formula which calculates each member state's contribution, they work over a long time scale and cannot help when there are major currency moves over a few months. In addition the special rebate recently agreed for Germany means that the normal mechanisms are watered down and sterling decline against the DM is effectively uncompensated. Best estimates for the extra 1996–97 CERN and ESA contributions, coming exclusively from currency movements, is about £10 million, which is 13 per cent of the total PPARC domestic budget. The consequences of having to deal with this sort of annual fluctuation in an intrinsically long-term programme do not need to be spelled out.

In the following table I draw the committee's attention to the level of the CERN subscription in real terms, corrected to 1995 pounds.

CERN Subscription in £ million, corrected to 1995–96 price levels

1985–86	*1986–87*	*1987–88*	*1988–89*	*1989–90*	*1990–91*	*1991–92*	*1992–93*	*1993–94*	*1994–95*
60.80	69.71	82.79	74.99	62.89	63.09	65.27	59.83	60.61	57.29

The figures for 1995–96 and 1996–97 are estimated to be £66.4 million and £74.3 million respectively. Expressed in Swiss Francs, the subscription has steadily fallen in real terms over the years. There are two possibilities; either the strong increase in the pounds costs of the CERN subscription will continue, or it will fluctuate as it has done over the last 10 years. In either case the government needs to do something to allow PPARC to plan rationally. I urge the committee to recommend that the government follow the lead of almost all the CERN member states and pay subscriptions to international bodies from some source other than the science vote. The level of the pound is presumably part of the overall economic strategy pursued by the Treasury, and it seems only equitable therefore that the Treasury should shoulder the burden of the consequences of its own policy. The amounts in question, while massive for PPARC, are entirely trivial in terms of overall government spending, and if the pound level fluctuates as it has in the past, removing the international subscriptions from PPARC at a level set at the average over the past 10 years will not even increase the total cost to the Treasury. It would however revolutionise the ability of PPARC to plan rationally.

IN SUMMARY:

(1) It is essential for the UK to participate in "Big Science" projects such as the LHC.

(2) UK scientists are currently able fully to exploit these facilities, despite pressure from lack of resources. However, these pressures must no be allowed to become worse. The single greatest problem with which government must deal is that of the cost of international subscriptions in pounds.

(3) In general the management of CERN is satisfactory. In the UK the management of particle physics is efficient, responsive and cost-effective. There have been extensive reviews over the past few years and suggested improvements implemented.

(4) There is a case for improving some aspects of PPARC's structure, in particular making the particle physics and astronomy committee chairmen members of Council.

I became a particle physicist 20 years ago because I was enthralled and excited by the quest for the ultimate constituents and forces in the universe. We are about to enter a new era when the LHC and other aspects of the particle physics programme promise the solution to fundamental questions such as the origin of mass and the difference between matter and anti-matter. Twenty years on, I still find this exciting and thrilling endeavour.

I am willing to give oral evidence if this would be helpful.

Memorandum submitted by the UKQCD Collaboration: I M Barbour and C T H Davies, University of Glasgow; K C Bowler, R D Kenway, B J Pendleton and D G Richards, University of Edinburgh; I T Drummond and R R Horgan, University of Cambridge; J Flynn and C T Sachrajda, University of Southampton; I G Halliday and S J Hands, University of Wales, Swansea; A C Irving, C Michael and C Parrinello, University of Liverpool; M J Teper and J F Wheater, University of Oxford. (12.12.95)

UKQCD is a national collaboration of seven UK university groups, whose mission is to increase the predictive power of the Standard Model of elementary particle interactions through large-scale numerical simulation of Quantum Chromodynamics (QCD), in order to determine the fundamental parameters of the Model and to seek signals of new physics.

We draw the Select Committee's attention to the close relationship between the development of leading-edge high-performance computing (HPC) and the particle physics phenomenology necessary to exploit fully the investment in large experimental facilities such as LHC and HERA.

— The highest energy experiments all involve accelerating and colliding strongly-interacting particles. In order to extract from the data any possible signal of new physics beyond the Standard Model, we must be capable of precise calculations of the strong force, ie, QCD. These can only be carried out using the most powerful computers.

— Particle physics stretches HPC technology to its limits. This provides "pull-through" for HPC technology, and the synergy between manufacturers and particle physicists has contributed to the design and testing of new computers. Through UKQCD, with the support of the Nuclear Physics Board of SERC and latterly PPARC, particle physicists established the first UK Grand Challenge project through partnership with Bristol-based computer company Meiko Ltd. in 1990. Meiko declared that this "*. . . pushed the 64 node i860 based Computing Surface to the limit*" and *"Strategically Meiko . . . has been able to gain gearing in the world supercomputing market because of it."* The Grand Challenge concept now forms the basis of a national programme spanning all areas of science.

— Particle physics attracts young people into scientific and IT careers. Graduate student members of UKQCD become highly skilled in advanced computing techniques and algorithms applicable to a wide range of simulation problems. Those of our students not continuing in academic research have readily obtained posts in the computing industry.

— Now that responsibility for HPC has been devolved to Reserch Councils, it is vital that PPARC has the resources to maintain state-of-the-art HPC facilities for its programme. This is essential, not only to maintain the health of UK particle physics, but to allow it to play a crucial role in the development of the UK HPC industry and ensure a continuing flow of graduates with advanced HPC skills.

Letter to the Clerk of the Committee from Professor A Howie, University of Cambridge (12.12.95)

I would like to comment on some of the issues before you from my perspective as Head for the past six years of a large laboratory aspiring to world leadership level not only in astronomy and particle physics but also in many areas of condensed matter physics and applied physics. Our current annual research grant income of £7.26 million arises from PPARC (£2.44 million), EPSRC (£2.23 million), BBSRC (£0.24 million), EU (£0.49 million), Charities (£0.23 million), Industry (£1.63 million).

Judging by the number of excellent projects which cannot be funded or which (like our own project for the Very Small Array in Radio Astronomy) languish despite their success at the pilot stage, the budgets at PPARC are under just as much pressure as in the other Research Councils. PPARC is however notable on two counts in my view. Firstly they clearly have a less equivocal commitment to basic science. Secondly they recognise the true costs of underpinning first class research and, unlike the other Research Councils which fully merit the strictures of the recent report on this topic by Coopers and Lybrand, PPARC have provided running costs honouring the guidelines of the transfer exercise. On both these counts the impact of PPARC's policies on the morale of our astronomers and particle physicists compared to their colleagues in solid state physics is already clear to me.

I would also like to support the well known view that astronomy and particle physics play an absolutely vital role in attracting the brightest young minds to science. Of course only a small fraction of them can expect to find long-term jobs in these fields so that the process of interesting them in and training them for other activities is crucial and a department such as this one should be a prime arena for such an effort. Here again I have to report that PPARC seems to me to have been much more constructive and helpful to us than EPSRC. To add to the natural advantages in training for overall organisation and communication skills offered in big science projects, PPARC has since its inception encouraged its investigators to interact more strongly with industry as well as with the general public. Significant progress has been achieved on both fronts. The pressures on EPSRC and its investigators to direct an enormous slice of their budget towards "useful" or "relevant" projects are by comparison much more severe so that basic research in physics shows clear signs of being squeezed out of their portfolio. An important bridge over which students initially attracted to astronomy and particle physics could be drawn over to solid state physics research and from there to materials science or engineering is in danger of being lost.

I have concentrated on giving my perception of PPARC's performance in running its affairs. I could also have waxed lyrical about the excellent research in international-level astronomy and particle physics as well as the formidable instrumentation development which they support. In case this aspect is of interest to your committee, I attach a statement sent to me by Dr M A Parker, a recently appointed lecturer in particle physics and a member of the LHC planning group. I will be happy to supply futher details of our astronomy programmes if you require them.

Statement by Dr M A Parker

Reply to the questions of the House of Commons Select Committee on Science and Technology.

The areas of physics covered by the PPARC include some of the most fundamental and exciting issues facing modern science. Investigation of the structure of matter at the smallest scales, and the observation of the cosmos on the largest scales, address the type of "big questions" which have propelled science over the ages: what is the world made of, how does it function, how did it begin, and how will it end. These questions are so basic to the role of science in society that every nation at the forefront of research wishes to play a part in their investigation. The public interest in these areas of science may easily be judged from the success of many popular science books and TV programmes on these questions. The desire to understand such questions is a major factor in attracting students to physics courses at Universities. The Large Hadron Collider project is the next high energy frontier, and it is essential that the UK community is fully involved, if it is to retain its current strong position in the field of particle physics.

The large scale facilities involved mean that any effort to answer these questions must be collaborative. This means that the research is carried on in the most cost effective way, by sharing large scale facilities such as accelerators, and major detectors. The UK community has exploited such facilities to the full in the past, and relies on the use of the LHC for its future programme.

The example of the Cambridge University High Energy Physics group illustrates the value of this international collaboration. The group has worked on a series of front line experiments based at CERN, including the Intersecting Storage Rings, the Super Proton-Antiproton Synchrotron, and LEP, and is now participating in the Large Hadron Collider project. In each case the group has been able to use its expertise to construct state of the art detectors developed at its laboratories in Cambridge. This work has increasingly been performed in collaboration with UK companies, most recently with support from the PPARC Particle Physics Industrial Support Scheme (PPIPS). After construction these detectors have been included in the overall experiment, and group members have taken a lead in the overall design. In conjunction with detectors supplied by other groups and other nations, the combined facilities have allowed first class physics results to be produced which would have been completely inaccessible otherwise.

It is a common misconception that large experiments address only a few issues. In fact, each new accelerator gives access to a wide new field of physics, a higher energies and smaller distances. For example, the OPAL experiment at LEP has produced around 150 papers since turning on in 1989, and has just begun a new phase of operation as the machine moves to higher energies. Each group in the experiment is then able to investigate particular issues suited to its expertise and interests, using a small team from the group, typically one senior academic together with students and perhaps a research assistant. Such physics analysis work is completely defined and performed in Cambridge, and presented to other collaborators for approval before publication. Students trained in this way acquire not only expertise in physics, but also experience in communication skills in an international arena, and of the execution of complex long term projects. The high value of these skills to industry has been recognised, and PPARAC has increased the number of awards for PhD places accordingly.

The PPARC structure appears capable of managing the programme adequately, if it is given the resources. No management structure can deliver a high quality product unless the necessary investments are made. In this context, it is extremely important that the Government honours the international agreements it has made, and ensures that the costs of subscriptions to CERN are funded, and allows for the effect of exchange rate fluctuations. In parallel, sufficient funds should be available in the domestic programme to make optimal use of the facilities provided via the CERN subscription. This will ensure that the returns to the UK are maximised, and that most cost effective use is made of the available resources.

Letter to the Clerk of the Committee from Professor R M Brown (11.12.95)

I am a particle physicist employed by CCLRC (Rutherford Appleton Laboratory). I am currently involved in two large experiments at CERN; the OPAL experiment at LEP and the CMS (Compact Muon Solenoid) experiment being planned for the recently approved LHC (Large Hadron Collider). At present I hold the elected position of Chairperson of the Collaboration Board of CMS which currently involves some 1,300 physicists and engineers from more than 130 institutes world wide. I emphasise that the views expressed below are personal and do not necessarily coincide with those of my employer or of the experimental collaborations in which I am involved.

Particle Physics is a cultural activity. The overriding justification for participating in this field of research is to contribute to the store of human knowledge and to help humanity better understand its place in the cosmos. It is unthinkable that any advanced nation should not be involved in such fundamental research. Quantifying the appropriate level of participation is more problematic. However, the material benefits which also arise from experimental particle physics should be taken into account when considering this issue. Among these are:

— Training of students; not only do students acquire highly marketable skills in technology and computing, but they also gain interpersonal and presentational abilities and they learn how to interact effectively in large multinational organisations

— Development of new technologies with applications in other areas, especially medicine and industry

— Stimulation of high technology industry.

The LHC will be the flagship of particle physics research over the next two decades. Experiments at this accelerator are confidently expected to make a tremedous breakthrough in our understanding of fundamental physics and cosmology. Furthermore the realisation of these experiments will pose unprecedented technological challenges. It would surely be a tragedy if the UK did not have a central role in this great adventure.

Since the 1970s UK physicists have been very effective in exploiting the facilities at CERN and have made leading contributions to many of the major experiments. Particularly noteworthy among these have been "EMC" which provided new insights into the internal structure of the proton, "UA1" which made the Nobel prize winning discovery of the W and Z bosons, and the very successful experiments, OPAL, ALEPH and DELPHI at LEP. This tradition is continuing into the LHC era with UK physicists playing central roles in both the large proton-proton experiments, ATLAS and CMS.

However, financial pressures are making it ever more difficult for UK physicists to maintain this influence. A particular problem has been the fall in value of the pound against the Swiss franc. This has increased our contribution to the CERN subscription, expressed in pounds, putting increasing pressure on the balance of funds available for "domestic" research. The problem is exacerbated becaused the "domestic" funds themselves must cover the cost of exploiting CERN, and an important element of this is the cost of travel which has also increased dramatically due to the change in the exchange rate. It is becoming increasingly hard for UK physicists to achieve an adequate level of presence in Geneva, either by "commuting" or by being based there for an extended period.

The mechanism for funding and controlling expenditure on ALEPH, DELPHI, and OPAL has been demonstrably successful. For these experiments, institutes or groups of institutes, supported by their respective funding agencies, took responsibility for specific parts of the detectors. Monitoring was provided at the national level by individual funding bodies, and at the international level by "Finance Review Committees" consisting of representatives from each funding agency and chaired by the CERN Research Director. The international community is still feeling its way to find the best method of extrapolating the LEP model to ATLAS and CMS, which are almost an order of magnitude larger, but I am optimistic that we will be successful.

The main problem as far as the UK is concerned is the increasing difficulty we are experiencing in planning with a reasonable degree of precision on a ten year timescale. PPARC has made considerable efforts to produce a firm 10 year plan. However, experience has shown that such plans can be subject to major changes on a timescale of 12 months or less, for reasons quite outside of PPARC's control. Other CERN member states seem able to plan for the long term with much greater confidence. A reasonable degree of stability is absolutely essential for successful international cooperation on large projects such as the LHC experiments.

As far as the research portfolio of PPARC is concerned, I am only qualified to comment on the particle physics component. In this area the level of funding is of critical concern. Even under the most optimistic of the various planning scenarios, the hardware contribution that UK groups will be able to make to the LHC experiments is significantly less than a "fair shares" calculation would require. Nevertheless the international standing of the UK community is such that UK physicists are welcome collaborators in these experiments and indeed are providing leadership in many areas. However, past funding restrictions have forced the UK to withdraw from several other important areas of particle physics research. Although the remaining programme addresses most of the fundamental open questions, it is generally acknowledged to be over focused. A modest increase in funding would allow a broader and much healthier coverage of the field to be achieved.

Parts of the PPARC structure which were inherited from the days of the SERC, in particular the Particle Physics Experiments Selection Panel (PPESP) and the Particle Physics Committee, have been tuned over many years and work well. Peer review by these bodies is accepted by the UK particle physics community to be conducted conscientiously and fairly. In contrast to some other areas of science, the relatively small number of particle physics experiments active at any time makes it possible to achieve an objective comparison of their relative merits and to apportion the limited resources accordingly. The system of managing the resources for these experiments through RAL is also generally accepted to be optimal because of its flexibility and responsiveness, and the small overhead it incurs.

Other parts of the system, for example the way in which large projects are passed up to Council for approval, are new and largely untested (at least as far as particle physics is concerned). I must therefore reserve my judgement on the effectiveness of the procedure, although I worry that distortions in the decision making process may occur because of the financial pressures under which we are currently operating.

Finally, I would like to emphasise the importance of RAL in contributing to and supporting the UK's involvement in particle physics. Its research physicists provide the glue for ensuring that UK university teams act in a coherent and consequently more effective way within large international collaborations. The technical expertise it provides in electronic and mechanical design, computing and other specialised areas such as superconductivity enables UK physicists to undertake responsibility for challenging and influential projects which would be beyond the abilities of even large university departments acting alone. Embedding this expertise in a large multidisciplinary laboratory benefits from synergy and enhances the ability to match supply to changing demands.

I hope that you find my views of some help in conducting your inquiry.

Memorandum submitted by Dr K J Peach, University of Edinburgh (13.12.95)

1. Particle Physics and Astronomy are appropriately joined in a single Research Council not because both are "Big Science" but because there is a close scientific connection, particularly between Particle Physics and Cosmology. This connection is developing rapidly as our understanding of the Standard Model of Particle Physics and of the implications of Big Bang cosmology evolves.

2. Both subjects require large instruments—necessarily large because of the intrinsic difficulty of experimentation at scales far from the human scale.

3. Particle Physics in particular has been successful in promoting international cooperation over many years. It should be a matter of great pride that in Europe we have two (CERN and DESY) of the three leading laboratories for particle physics.

4. One of the problems at CERN over the past few years has been the apparent desire by the UK to micro-manage the CERN budget. This has meant that measures which have a short-term expediency often have long-term effects which tend to increase costs to the UK; political considerations may conflict with the judgement of physicists. The CERN subscription is a large fraction of the total budget for particle physics in the UK largely because of the reduction in the domestic budget in real terms over more than 10 years. Variations in the costs of the CERN subscription caused by the continuing decline in the £ relative to the Swiss franc combined with the failure to compensate for exchange rate fluctuations—beyond the control of particle physicists—lead to a dramatic squeeze on domestic expenditure. This is amplified by the fact that much of the domestic spend is also inflated when the £'s purchasing power diminishes and is inadequately compensated through the indexation. The fundamental problem is not the CERN budget—which has been more or less constant in real terms over many years—but the weakness of UK currency.

5. I believe that it is important for the UK to continue to play a major role in particle physics. The progress in understanding over the past 20 years has been quite remarkable, leading to our present "Standard Model" of Particles and Interactions. There is general interest in the most basic constituents of the universe around us, and it is a significant factor in attracting students into physics. However, it is, still only a "model"—that is, it describes but does not explain. In particular, there are three open—and probably related—questions for which new ideas and new experimental information are required. These are; the mechanism through which particles obtain mass; the reason why there are three generations of fundamental particles when only one is needed to construct the "everyday" universe; the origin of the dark matter of the universe. Subsidiary questions—contained in the above—include whether the neutrinos have mass (they probably do) and what determines the masses of the particles, once the mechanism through which mass is obtained is understood. Finally, and this brings us back to cosmology, is it possible to incorporate the matter-antimatter asymmetry of the universe and gravity into the fundamental description; this almost certainly requires a new mathematics.

6. The reason for doing particle physics and astronomy is partly cultural. The traditions of enquiry into the working of the material universe began in pre-history and continued through several millennia. In raising these questions, and seeking answers, many obstacles have been swept aside—mathematical tools have been

developed, new technologies created, existing technologies pushed to the limits. In turn, these developments have been used in other sciences and in the wider world. Examples abound, but include not only accelerators and detectors (used in medicine and increasingly industry) and mathematical techniques, but also advances in electronics, instrumentation and computing. (The World Wide Web was developed at CERN by physicists to solve a particular problem of communication between people separated by relatively large distances, and the need to have ready access to potentially large volumes of information; it was not developed by a computer science department on a collaborative project with the computer industry. Incidentally, the Internet upon which it is built was designed to solve a military problem—the need to have a network which had no centre and therefore could not be crippled by a single blow.)

7. The committee posed several direct questions. In view of the above, I make a brief response to each.

— How important is it that the UK continues to participate in "big science" projects such as the LHC?

It is important that the UK continue to support particle physics for the reasons given above. In addition, particle physics is part of the general fabric of science, and science as a whole is far more interconnected than the divisions imply. Techniques—mathematical and instrumental—cross boundaries rapidly, and to retard any of the forefront sciences eventually risks endangering the whole. It is *because* the UK must remain active in particle physics and that the next major step in particle physics requires the LHC that it should support the LHC; the fact that it is "big science" is a consequence. The UK does not need to join large scale projects just because they are large scale, but most certainly should where the scientific case is strong—as it is in the case of the LHC. We should also be proud of the fact that CERN is the outstanding example of excellence through international cooperation; CERN has shown that it *can* be done.

— Are UK scientists able fully to exploit this type of collaborative facility?

There is no doubt that UK scientists are able to exploit the opportunities available; however, the continued decline in domestic funding over the past decade or more weakens our position relative to the other major countries. So far, we have been remarkably successful in *doing more with less.* As an example, in my experiment on matter-antimatter asymmetry (part of the second question mentioned in section 5) the support per UK physicist is less than half that of my collegues from France, Germany and Italy, despite the fact that it is consistently rated a high priority programme within the UK and at CERN.

— How should major international projects be managed and funded?

I see no fairer way of apportioning costs than a formula based on some measure of relative wealth. This is particularly true of projects with a long life cycle, where stability of funding is important. In particular, proposals for funding such as a fixed percentage of costs is unstable since it does not track national wealth and can (for a declining economy) lead to *excessive* costs. Fixed contributions in national currency do not allow for stable planning over a 20 year period in a period of currency and turbulence.

I believe that the facility management should be allowed to, and expected to, manage effectively, with the international council which guides the organisation, fulfillng the role of the shareholders at the AGM—defining the goals, monitoring the performance against goals, agreeing the overall budget and checking the efficiency of the organisation. A powerful local management is better able to determine spending priorities than an occasional meeting of politicians.

— How appropriate is PPARC's structure for its research portfolio?

The broad organisation is appropriate, However, there is a problem in that the Chairman of the Committees which are responsible for determining the policy objectives, made up largely of physicists, are not members of Council, This means that the advice is passed to council via the executive. In my view, this gives the executive too much formal power. This is *not* a criticism of the present executive. However, I believe that the Chairman of the principal committees should be members of Council, should make the scientific presentations in their areas to Council and participate fully in the discussions of all matters; the role of the Executive is to comment upon these, and to implement the decisions of Council.

Memorandum submitted by Professor Robin Marshall, The University of Manchester (13.12.95)

1. It is important to make the distinction between the UK Particle Physics Programme which is carried out by active scientists with peer review and PPARC which is an administrative layer between the Particle Physics Programme and the route for government funding.

2. There are strong attitudes to PPARC which are the residue of the 25 years of SERC: a large body which often appeared remote from the science and which had among its hierarchy, some prominent people whose attitude to the science was questionable. Fortunately, such people have now disappeared and the PPARC employees who are visible to particle physicists are now much more committed. In addition, throughout the 1980s, when particle physics reduced its financial turnover by more than the amount recommended by the Kendrew report, SERC was almost the only growth sector in science, with a steady rise in number of

employees and overhead costs. I strongly recommend a close scrutiny in the number of research council posts (a) now, (b) just before the restructure and (c) 10 years ago.

3. I have many years experience of the German laboratory, DESY, which has direct links with their appropriate government ministry. The research council administrative layer does not exist, nor does it appear to harm their research ability, quite the opposite. There is also a massive saving on salaries and infrastructure which the UK incurs through its research councils.

4. After the restructuring of the research councils, particle physics has now moved to essentially a two council system with PPARC and the Rutherford Appleton Laboratory. This seems unnecessarily cumbersome, expensive and likely to cause inertia. Already PPARC has farmed out its responsibilities for postgraduate students to EPSRC which means that all decisions about students are made on financial rather than scientific research grounds.

5. There now appears to be only a handful of PPARC employees who are directly responsible for the administration of rolling grants to University particle physics groups and other parts of the particle physics community. This is partly due to the fact that particle physics is organised so that there are only a few large grants which are renewed every two years. I strongly recommend a close look at the way grants and administered in the particle physics and astronomy sectors which appear to be quite different. I also strongly suggest a close look at type of personnel employed at PPARC to see if they are all relevant to their "mission". The number of people working on particle physics administration at PPARC is now so small that one should really examine closely the possibility of combining their function with that of the Rutherford Appleton Laboratory. This is one of the strongest suggestions I can make in this document. If astronomy grant were organised in a similar way to particle physics, it seems almost feasible that the whole of PPARC's current activities could be done by two handfuls of extra staff at RAL. At present, there are areas like Publicity and PR which appear to be duplicated.

6. It is impossible to address the question about the UK's participation in "big science" projects like LHC without being biased. It is possible however, to point to the huge differences in philosophy between Europe and USA on the question of projects like LHC where Europe, with UK playing a strong role, produced a proposal for LHC which was financially sound whereas the USA proposed an unbelievably expensive green field proposal which failed spectacularly on financial grounds. Purely from the point of view of my personal culture, I wish to see the UK continue to participate and take a leading role in large projects like LHC for particle physics, Jet for fusion, the Synchrotron light source at Grenoble, telescopes and arrays like Merlin for astronomy etc etc, because it is consistent with the national culture and history of this country, which I am proud of.

7. The particle physics community developed a habit in the 1970s of closing down projects like NINA and NIMROD in order to participate in the leading accelerators at CERN and DESY and to enhance the quality of the science. At the present time, they have also cut their current programme in order to make a minimum base line investment in the future of LHC. Already in the current international experiments at the German accelerator HERA, the British groups have made a lower *pro rata* contribution than most other countries, including some of the former Eastern block. This is in order to fund the R&D needed to build experiments for LHC which need equipment which is beyond current technology.

8. For the first time in the 30 years since I obtained PhD, British groups working at overseas experiments are funded at such a low level that they can no longer travel at a viable level to supervise their research students on site or to take a full role in the experiment. There have been funding crises in the past. SERC was famous for its "October crises" when spending was suspended for a few months, only a frenetic resumption to take place in March before the end of the FY. However, these were always temporary, whereas we have slipped into a culture of poverty during the current FY and the reasons are not totally clear. PPARC was reported to have been allocated an amount to deal with the hike in the CERN subscription. But an amount equal to this still disappeared from the community's disposable income. This has coincided with the start of PPARC and a surge in new ways to allocate funding (eg ROPA & PIPPS) which are not targeted at the direct research programme. There is a serious funding crisis in the current experimental programme which makes it barely viable. This becomes very difficult to accept when the deficiency in the travel budgets which cause this crisis is less than (say) the annual pay rise of a privatised company chairman, or the amount that is being distributed *by anonymous non-peer review in private* to ROPA and PIPPS schemes. The current display of personal and corporate wealth in the above-mentioned privatised companies has become the new unacceptable face of Britain and is totally alien to our normal cultural aims.

9. Fluctuations in currency exchange rates have historically caused shock waves in the particle physics world, due to the impact on the CERN subscription. But the fluctuations are always in the same direction and have been relentlessly consistent for 35 years. It was extremely disappointing to see that the first currency fluctuation in the history of PPARC, no bigger than any of the others and no less predictable, has almost brought our programme to its knees. Whenever this happens, ministry sources and council officials publicly blame each other, ignoring Mark Twain's advice not to argue in public with a fool. Whatever the correct way to manage and fund international science projects like CERN is, *the UK does not have it.* I suggest one way in the next section.

10. I have seen the German laboratory, DESY build and operate large accelerators and carry out a research programme at the leading edge for 30 years. I have worked for them, served on their committees,

lived there for 5 years and commuted for the rest. I have seen them experience what they have described as financial crises but which I would welcome as a healthy permanent scenario for doing research. As well as contributing to CERN at a level higher than UK, they also maintain a domestic particle physics programme which is larger than the UK's CERN programme. The most important feature is that their budget for doing experiments at CERN and home is not affected by variations in Swiss franc and the Deutsche mark. They are lucky. The last 35 years say that the pound will continue to fall against the Swiss franc and this is a fact of life. A way to get out of this is to shift all the responsibility for administering the international financial allocations into the appropriate expert ministerial office (OST) and to shift the scientific management of the projects to a single expert body like the Rutherford Appleton Laboratory. The problems are then matched to experience, skills and resources. The government can handle financial matters like the CERN subscription, whereas the research councils have shown over and over again for 25 years that they cannot. Responsibility for the consequences of currency fluctuations then rests where it belongs. A single body (council) with a strong scientific and technological base like RAL, can manage the science and technology. This is the German model and it works. The UK has used a different model for over 25 years and it does not work. So far, PPARC has not existed long enough to be written off or given the highest accolade, but I do not believe that it has been given the resources to solve this fundamental problem which particle physics still faces.

Memorandum submitted by Professor Ian Butterworth (21.12.95)

(My credentials for submitting evidence are summarised in Appendix 1)

INTRODUCTION

The changes in the remits and structures of the Research Councils announced in 1993 were implemented only on 1 April 1994, and there has, as yet, been little time to assess the consequences. Fortunately, PPARC has a mission to support fundamental science which differs little from that of the former appropriate Boards of the SERC. The main problems lie with EPSRC, as was predictable when "big science" was separated into its own research council with the danger of producing "a situation in which there will be, on the one hand a research council for high-profile, internationally regarded, curiosity-based research protected by international treaties, and, on the other, a rump of unexciting, parochial "British" science".[1]

Whilst it is understandable that the Committee should examine whether the structures and mechanisms within PPARC are appropriate, but then to again ask how important is it that the UK participate in "big science" projects adds to an excessive frequency of review. For particle physics we have had in the last 10 years:

(1) Report of Group set up by ABRC and SERC to Review UK Participation in the Study of High Energy Particle Physics, (Chaired by Professor Sir John Kendrew), June 1985.

(2) The CERN Review Committee, (Chaired by A Abragam), 1987. Set up because of strong British pressure.

(3) SERC Review of Particle Physics in the UK, (Chaired by Dr A Ledwith), 1992.

(4) The Report "The Nature of Matter, International Collaboration in Particle Physics", Parliamentary Office of Science and Technology, June 1994.

(5) OECD Megascience Forum, (Chaired by P Tindemans), OECD Comittee for Science and Technology Policy, 1994.

All of which concluded the importance of the science and commended CERN as the model for international collaborative ventures. And:

(6) The very detailed international discussions and negotiations leading to approval by the 19 CERN Member States of the Large Hadron Collider, (December 1994).

Given that particle accelerators take 10 years to build—LHC will not operate before 2004, the frequency of review might make our overseas partners suspect our political commitment to international collaboration.

HOW IMPORTANT IS IT THAT THE UK CONTINUES TO PARTICIPATE IN "BIG SCIENCE" PROJECTS SUCH AS THE LARGE HADRON COLLIDER?

The scientific importance of the Large Hadron Collider, (LHC), has been well described in the report: "The Nature of Matter?" from the Parliamentary Office of Science and Technology [2], which relies heavily on the SERC report "Particle Physics 2000" [3]. Though written in 1991, the research goals which the latter describes are still valid, for the subject requires long term planning. The importance was recognised not only by the 19 Member States of CERN when they approved LHC, but by a number of Non-Member States who now wish to join the project. Japan was the first to commit itself. The Drell Panel has recommended to the US Department of Energy that it provide substantial financial contributions, and negotiations with CERN are starting. (It is encouraging that, despite recent budget reduction in the US, that for High Energy Physics by the DoE has not been cut). Canada, Russia, India and Israel have all announced their wish to be involved.

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[1] Independent Newspaper, 31 May 1993.

[2] Parliamentary Office of Science and Technology, "The Nature of Matter?—International Collaboration in Particle Physics", June 1994.

[3] SERC Particle Physics Committee, 1991, "Particle Physics 2000", SERC, Swindon.

Why is there such enthusiasm? Certainly, investment in large projects brings some direct commercial benefit, and leading-edge research stretches technology—the most recent example is CERN's creation of World Wide Web for Internet which is transforming the distribution of information and thus the publishing and media industries.

But I believe that the main reason for the enthusiasm is a much deeper one, and one that is very encouraging. It is the wide spread recognition, at all levels of society, that our attempt to understand the nature of the Universe which we inhabit, is one of Man's greatest aims, an important aspect of the human spirit.

Certainly it is the view of many of the young. There is today a wide concern that we will not have enough scientists and technologists to provide for future national economic success. But those of us who teach in physics departments know, that of those who do enter science, they do so because they were initially attracted by fundamental and basic issues—even though they know very well that few will become professional particle physicists or astronomers. Were the UK to opt out of such "big science" projects we would be sending out an appalling signal to them.

But not only would our young be cheated in the short term. The complex living organism making up the science and technology on which our future must depend, would start to rot if the basic science which is its root were cut.

ARE UK SCIENTISTS ABLE FULLY TO EXPLOIT THIS TYPE OF COLLABORATIVE FACILITY?

There are two parts to this question: What is the quality of British particle physicists? Do they have the appropriate resources?

The first can be answered easily. The UK particle physics community has for many years been particularly strong. This is illustrated by the fact that the current CERN Director-General and the LHC Director are both British. Britons carry senior positions in the development of both of the two LHC detectors.

But in terms of resources, there is no doubt that British physicists find it harder to exploit CERN than their colleagues from Germany, France or Italy. That is why Britain has found it hard to persuade other countries that costs should be cut at CERN. Only Germany traditionally joins the UK in pressing for reduced costs at CERN, and Germany, of course, runs its own world-class particle physics accelerator laboratory giving access to physicists from other countries, including the UK. In continuously demanding for reduced central costs, the UK advertises itself as the champion of efficiency, but outside we are more frequently viewed as attempting to enjoy international research on the cheap, with an inappropriate domestic support for its researchers.

Certainly, one of our problems is self-inflicted, or more correctly inflicted by our Treasury. In no other member state does the government simply toss the problem of changes in exchange-rate straight to the research agency whether, in our case, it is PPARC alone or the combined Research Councils.

PPARC, under financial pressure, understandably seeks to reduce central costs, and argues that the appropriate balance of international and domestic spend should be one-to-one rather than the current two-to-one. Though such a balance is indeed probably correct, it is completely unrealistic to believe that the other states will see CERN damaged to the degree needed to solve the British problem.

HOW SHOULD MAJOR INTERNATIONAL PROJECTS BEST BE MANAGED AND FUNDED?

(a) *Funding*

The programmes of CERN require formal international agreements. Once negotiated, the appropriate funding should be ring-fenced at a governmental level, ie at the level higher than that of the Research Councils, so that other programmes whether in PPARC or the other Research Councils are unaffected by subsequent changes in exchange-rates or formulae for international contributions. This would imply a greater involvement of the Foreign Office and the Treasury in negotiations with other member states and the CERN Management.

(a) *Management*

CERN has an enviable reputation for the management of its projects, which have always been completed on time and within budget. Therefore there is no need to change management arrangements.

It is not wholly obvious why CERN has proved so successful, but I can identify four contributary reasons. Firstly, those involved, either on CERN staff or as CERN users, have been selected to be of the highest quality. Secondly, they are very committed and determined to make CERN a success. Thirdly, management is very interactive, and all policy decisions from detailed experimental programmes up to strategy policy debates come from active scientists; it has proved possible to organise formal arrangements that blend the experience of older scientists with the up-to-date awareness of younger scientists. Fourthly, international projects can exploit the different skills, approaches and backgrounds of the members from different countries.

CERN traditionally would include as an element for its success, the absence of "juste retour" in its contracts and is perhaps concerned at a growing element of it in the agreements for LHC. However, in practice, the large CERN detectors are primarily funded from the domestic resources of the participants, and, as for the HERA project at DESY, there is a large element of "provision-in-kind"—a specific form of "retour". Yet the complex contractual arrangements, whilst not following normal CERN conventions, are still operated successfully.

How appropriate is PPARC's structure for its research portfolio?

It is too early to assess the consequences of the changes in the remits and structures of the Research Councils, or of the much more worrying transfer of the OST and its Councils to the DTI (particularly in the case of PPARC which in the short term can never hope to "pay its way").

There is general recognition within the particle physics community that everyone involved is trying to make the new structures in PPARC work, but I believe that the changes that have been introduced are unfortunate and will eventually have to be reversed. Under the SERC arrangements a Particle Physics Committee existed where recommendations and views of the various peer-review sub-committees could be brought together in order to develop a coherent set of priorities. Now the peer-review sub-committees report direct to the PPARC Executive and priority decisions must be made by the Executive or decided at Council level. The Particle Physics Committee whilst still existent has no obvious role. A useful intermediate level for programme coordination has been eliminated with the danger of unnecessary conflict or uncertainty.

A second issue is the role of the Central Laboratory of the Research Councils and in particular the Rutherford Appleton Laboratory. The detectors needed for particle physics require large and complex elements too large to be developed in university laboratories but which can form part of our domestic support of the CERN programme. The UK with its Rutherford Appleton Laboratory, France with its Saclay laboratory, Holland with NIKHEF etc., have made very successful use of such national laboratories using them, in part, as an interface with domestic industry. It has also proved desirable to provide at national laboratories some of the data analysis of experiments, again providing computing facilities intermediate between those at CERN and those at the university groups. It is important that in any changes resulting from the Next Steps Review of CLRC, the needs of British particle physicists are still met in a satisfactory way.

Since the main purpose of the Central Research Laboratory is to support university research groups from a wide range of subject areas, it would be appropriate if the Laboratory were managed by a consortium of British research universities in a way analogous to the US Brookhaven National Laboratory.

Summary

The growth over the last few years of our understanding of the fundamental nature of the material world has been quite remarkable. It is now at a fascinating stage where we glimpse hints of deep connections between the microscopic structure of matter and the history of the Universe since the Big Bang. Questions abound which surely cannot be answered by LHC alone, but the results that will be obtained from it are pivotal and its approval has ensured a continuing progress in our understanding.

It is vital the UK plays its full role in this intellectual adventure, particularly since our economic future depends on stimulating a lively, knowledgeable and committed cohort of scientists and technologists.

But without changes in the funding arrangements, the UK will not be as able to exploit international facilities like LHC as other, comparable, European countries.

APPENDIX 1

I was formerly Head of the High Energy Particle Physics Group and of the Physics Department at Imperial College. During that time, I chaired the Nuclear Particle Physics Board of the Science and Engineering Research Council and hence was one of the two UK Delegates on the CERN Council between 1979 and 1983, ie through the period of approval of the LEP accelerator complex, the major particle physics facility currently operating. I had previously chaired the CERN Super Proton Synchrotron Committee, the SPS being the main facility prior to LEP.

From 1983 to 1986 I was seconded to CERN as Research Director as the LEP experiments were set up. As the most senior Briton on the CERN management, I was therefore necessarily deeply involved with providing CERN's evidence, oral and written to the Kendrew Review in 1985. My experience of CERN-UK relations has therefore been a long one starting in the late 1950s.

When I left CERN to become Principal of Queen Mary and Westfield College my direct involvement stopped, but now as an Emeritus Professor I have returned to particle physics research as a Senior Research Fellow at Imperial College.

Letter to the Clerk of the Committee from D Newbold, University of Bristol (12.12.95)

Regarding the Select Committee enquiry into PPARC: I would like to take the opportunity to present to the committee a point of view which may not have been expressed from elsewhere—that of a particle physics student without PPARC support.

In common with an increasing number of PhD students in Britain, I am provided with a maintenance grant by my university as part of a scholarship. In my case, the University of Bristol guarantees to match the equivalent PPARC grant, but offers little contribution towards expenses incurred as part of my course, It is my belief that this is the basis of a serious inequity with PPARC-funded students, which adversely affects the ability of those in my position to produce high quality work within the time allotted. (This period is currently three years, with no possibility of extension, strict financial penalties being imposed by the University in an attempt to enforce this. It is surely debatable whether this is anyway a fair time limit, considering the somewhat different working conditions faced by particle physics and astronomy students in comparison to those supported by, for example, the EPSRC).

The first, and arguably most serious, problem is the lack of provision for travel. As the committee is aware, PPARC invests heavily in interational facilities aboard, and the majority of particle physics experiments take place outside the UK. PPARC therefore provides funding for its students both for short-term attendance at meetings and facilities abroad and for long-term visits. (It is the norm for PPARC-supported students to spend a year, in many cases longer, at the site of their experimental project). In this way, our use of shared facilities is maximised, and students are able to contribute more easily to the running of the experiments, learning in return from the expert physicists around them. Unfortunately, the travel opportunities for non-PPARC students are much more limited, since the cost must be extracted from experimental budgets or other sources. This is particularly relevant to students working within the proposed LHC experiments, for which travel funding is so far minimal, and is used mainly by senior members of the collaborations. It would seem inevitable that the training of such students must suffer in quality as a result.

There are other ways in which the funding by universities falls short of that provided by PPARC. In particular, PPARC provides a range of training, careers and skill development courses for its students, which may only be attended by non-PPARC students on payment of a fee—in general, the cost of one such event would exceed the provision made by the univeristy for a whole year by a considerable margin.

From a student's perspective, it would appear that PPARC takes its responsibilities for training extremely seriously, the recent report of the Education and Training Committee emphasising the need for careful monitoring of the quality of PhD courses and of their intake. PPARC is also notable for its efforts to stay in touch with and gather opinion from its student body. However, if these measures are to apply only to those directly funded by PPARC, it is possible that some students could emerge from a PhD course having "slipped through thet net" of quality assurance. This is somewhat ironic, as university scholarships are often portrayed as being in some way prestigious, possibly attracting the best candidates.

It would be easy to take the attitude that PPARC bears no responsibility for those students not dependent upon its direct funding, and that perhaps the burden should lie with the physics departments who recruit university scholars. Since the probability of extra funding from university sources seems small, however, the expense of maintaining the quality of training must eventually come from the research council by one route or another. It is also arguable that PPARC has a responsibility to provide the greatest possible opportunities for all students, in the sense that it must maintain a supply of motivated high-quality scentists for its future research programme, and that it must exploit shared international facilities to the fullest extent. Therefore, it would seem sensible for PPARC to examine this issue and consider introducing a more flexible funding system for the training of university-maintained students.

Letter to the Clerk of the Committee from the Department of Physics and Astronomy University of Edinburgh (12.12.95)

We write on behalf of the Department of Physics and Astromomy to express its view that the UK should sustain its research effort at the forefront of particle physics and astronomy for the following reasons:

1. Particle physics and astronomy address some of the most profound questions in science, which are of intrinsic general interest.
2. An increasing and substantial fraction of students coming into Physics at degree level have been attracted by particle physics and astronomy. In Edinburgh, almost a third of our Physics intake is onto a mixed physics and astronomy course. Equipped with important scientific and technological skills, our graduates go on to a wide range of careers.
3. Because the questions asked involve distances so far from the human scale, large and sensitive instruments are required: high energies to explore particle structure at the shortest distances, high sensitivity to detect the faintest signals from the remotest parts of the universe.

4. Particle physics and astronomy are increasingly interdependent and share common objectives, such as understanding the Big Bang, the preponderance of matter over antimatter in the universe, and the nature of dark matter, so that the organisational structure provided by PPARC is appropriate.
5. The requirement for big experiments has internationalised the science, one of the few areas of human activity demonstrating benevolent international cooperation and competition.
6. At PhD level, particle physics and astronomy again attract students of high calibre. Their research provides training at the forefront of technology, computing and mathematics. A recent survey commissioned by PPARC shows that their eventual employment prospects are much better than average.
7. The research drives technological developments. Examples include microelectronics, superconducting magnet technology, medical and industrial accelerators, high-performance computing and networking, the World Wide Web, image processing, satellite technology, and adaptive optics.
8. The UK has an outstanding track record in particle physics and astronomy. Progress during the last 30 years has been beyond expectations. We are on the brink of important discoveries such as the Higgs boson, and more fundamental understanding of all four forces of nature and their relation to the origin of the universe.

Professor P W Higgs, FRS,
Professor P N Pusey
Professor R D Kenway
Professor M E Cates
Professor G S Pawley, FRS
Professor C A Greated, FRSE
Professor A Lawrence
Professor A C Shotter, FRSE

Letter to the Clerk of the Committee from Dr C N Booth, University of Sheffield (12.12.95)

I understand that a House of Commons Select Committee is conducting an enquiry into PPARC, the Particle Physics and Astronomy Research Council, and the subscriptions to the international research agencies CERN and ESA. As a University lecturer and researcher in physics, I would like to express my views on what I believe to be a very important area.

There are a number of reasons why I believe it is essential for Britain to maintain its place in the forefront of research into the fundamental laws of nature. Perhaps foremost amongst these is one which could be considered cultural—a society which looses its basic curiosity and drive to understand the world around it is bound to stagnate. However, there are also many practical benefits to be obtained from the conduct of such research, and by the involvement of this country in such activity. As a lecturer, I am sure that the insights obtained from the study of the very fundamentals of the universe are extremely useful in the understanding, and the teaching, of the applications of physics in the modern world. There are, however, also direct benefits from the conduct of the research.

Membership of CERN is expensive because the conduct of particle physics is a highly technological exercise. Much of the money which pays the CERN subscription therefore finds its way back into industry through contracts to supply specialised equipment. (Sadly, Britain has not benefited from this to as large an extent as it should in the past, but I understand this position is improving.) Perhaps more valuable, however, than the financial returns have been the transfer of skills and technology from a "pure" research organisation into industry, where they have found much wider application. By its very nature, particle physics relies on techniques which are at the very edge of what is currently possible, and so is a perfect breeding ground for new solutions to new problems. This spin-off has been felt in a wide range of areas, but perhaps nowhere so dramatically, over the last 20 years or more, as in the field of medical physics. Techniques originally designed to provide pure, unapplied knowledge of fundamental particles and their assemblages in nuclei, such as nuclear magnetic resonance, are now used as routine diagnostic tools in every major hospital. Similarly particle detectors are used for imaging the human body, for example in positron emission tomography. Even the accelerators themselves are now medical tools, with beams of particles being used in the treatment of tumours. None of these devices or techniques was originally developed for an application outside that of the search for knowledge, but all have rapidly been exploited to the benefit of the public—and the commercial advantage of the companies that produce them. Medical applications are only one example; I could equally well have chosen the hardware and software developments or electronics advances pioneered by this branch of physics. I am sure that techniques which are currently under development, and in some instances are highly speculative, will in many cases also move into the commercial arena, whether it be in medicine, computing, communications or elsewhere.

In my view, there is only one worry about the high cost of our subscription to CERN (and I presume ESA, where I have much less knowledge). It seems to me of no doubt that this subscription is of great value, but it is important that the domestic particle physics and astronomy budgets are not cut back so far, in order to pay the international dues, that British universities and research institutes are not able to play their full part in the international organisations, and so obtain the appropriate benefits, both in knowledge gained and technological spin-off. I understand that many other European countries separate the payment of international subscriptions, which come under the budget of their Foreign Office or equivalent, from the spending on domestic research. I would suggest that this is a much more stable system than ours, where research grants, and so money for both personnel and equipment, suffer from the vagaries of the Sterling exchange rate.

Letter to the Clerk of the Committee from Dr D L Johnson, University of London (13.12.95)

In response to your call for input to your committee from UK particle physicists I offer my views on the following questions:

(1) How important is it that the UK continues to participate in "big science" projects such as the Large Hadron Collider (LHC)?

As a young particle physicist who joined the field when the Large Electron Positron collider (LEP) was being commissioned and who has therefore only seen particle physics in its "big science" era I can only reflect that the disparaging way in which this term is often used by many older scientists is a result of their reflecting on their own "golden years" and not actually the result of any objective worsening of the quality of science carried out. So that whilst many would contend that the huge amount of effort involved in carrying out a modern physics analysis: the engineering; the electronics; the computing; the software etc somehow "dehumanises" the whole endeavour compared to the days when one could make useful measurements with "tabletop" scale equipment. I and my contemporaries would argue that large collaborations actually help to "humanise" the scientific community and the scientific process as a whole by forcing greater openness, communication and understanding both nationally and internationally. I therefore feel that the need to participate in these projects is very important to allow British scientists to develop fully in the more European times in which we now live.

(2) Are UK scientists able fully to exploit this type of collaborative facility?

Yes! Even were all other things equal, I think that most would concede, as many of my non British colleagues frequently do, that having English as a mother tongue is a great advantage in particle physics and indeed science in general. It helps greatly in both verbal and written communication meaning that young British scientists can present their results very clearly to their colleagues and peers, read without hindrance any publication, documentation or manual and help greatly in the preparation of any new publications. Add to this the fact that the British character lends itself well to teamwork and that many world renowned particle physicists are British and you can see why we do very well from collaborations of this type.

(3) How should major international projects be managed and funded?

I believe that the only practicable solution to the management of a major international scientific project is a committee consisting of policy makers and senior scientists. The policy makers to ensure that political and monetary guidelines are followed and the senior scientists to ensure that a serious scientific programme remains intact. The funding of these projects should be managed in the same way as is that of the many other international collaborative efforts: the UN; WHO etc.

(4) How appropriate is PPARC's structure for it's research portfolio?

Whilst I can't claim to be very knowledgeable on the structure of PPARC I can say that after attending this summer's meeting of younger researchers I was left with a very positive impression of PPARC as a body of people with the very clear aim of representing the opinion of all PPARC related scientists from the "grass roots" level up. I am very happy with this more open policy and can only hope that it continues to develop.

I hope that my comments have been of help and look forward to the results of your enquiry.

Letter to the Clerk of the Committee from Dr P N Ratoff, University of Leicester (13.12.95)

I have been actively engaged in particle physics research for nearly twenty years and have experience of working at several major accelerator laboratories around the world. I have been employed by academic institutions in both the UK and the USA and have, therefore, some direct experience of how this research is conducted and administered on both sides of the Atlantic. I have played a fairly prominent role in the construction and data analysis of one of the four major experiments at CERN's LEP machine.

It is my firmly held belief that it is vital that the UK continues to be involved in Big Science projects like LEP and the LHC at CERN. The need for large and expensive apparatus is a somewhat perverse, but entirely necessary, consequence of trying to investigate the structure of matter at the shortest possible distance scales.

Many of the deep and profound questions which our present knowledge permits us to ask, can only be addressed by an even more powerful accelerator than is presently available. The current machine, LEP, has been a remarkably successful endeavour, which has provided an enormous quantity of new and important information. It will certainly be seen as a crucial step along the path of knowledge and understanding. However, there are a number of questions which LEP will probably not be able to answer, and so, for this reason, we must take the next step. There is a definite consensus in the particle physics community that the LHC is the best machine to build next.

As a university teacher involved in the admissions process I have seen clear evidence that particle physics is repeatedly mentioned by our applicants as one of their main reasons for wanting to study physics (astronomy and cosmology are the other "inspirational" subjects mentioned). Furthermore, my colleagues and I at Lancaster, who are actively engaged in aiding the pubic understanding of science, have detected a very strong interest in this subject by members of the general public, who have attended various open-days and other events that we have arranged. I therefore strongly believe that the public interest in this research definitely warrants its continuation and, ideally, a return to the funding levels (in real terms) of ten to twenty years ago.

A particular problem in recent years has been the detrimental effect on the domestic research budget caused by Sterling-SwissFranc exchange rate changes. It really would make a lot sense, if we are to properly exploit these facilities, that Government could find a mechanism to protect the domestic budget from large increases in the CERN subscription. Obviously, now that CERN is the recognised world-centre for particle physics (and we are fortunate in having an outstandingly good British Director General at the helm) it would also be desirable to see CERN membership expand to include more states, especially the richer nations like the USA and Japan.

Thanks to the excellent support provided by PPARC, university physicists like my colleagues and I, have been able to participate on an equal footing with our international colleagues in large collaborative ventures at CERN and elsewhere. We are able to contribute to the comments on a broad range of activities (including UK technological know-how and scientific leadership) and have succeeded in fully exploiting the substantial investment that the UK has made in them. It therefore seems to me that PPARC is doing a very good job in managing its research portfolio.

Letter to the Clerk of the Committee from Professor J D Dowell, University of Birmingham (14.12.95)

I welcome this opportunity to provide evidence relating to the work of PPARC of which I am currently a member. In the past I have been Chairman of the SERC Particle Physics Committee from 1981 to 1985 and for eight years a member (ad hominen) of the CERN Scientific Policy Committee (SPC). At present, as chairman of the LEP Experiments Committee, I am on the CERN Research Board, which is chaired by the Director General, and ex-officio on the SPC.

I will concentrate my remarks on CERN and particle physics but would first like to acknowledge the outstanding quality of UK astronomy, both ground-based and in space. All of the activities supported by the PPARC have an excellent reputation worldwide for scientific leadership and achievement and the quality and reliability of the instrumentation provided by UK teams.

There is, however, currently a crisis in the level of domestic funding which is needed to carry out the research, in particular to exploit adequately the investments made at CERN and ESA. This is partly due to the relative decline in the value of the pound which has forced up the contributions to these organisations, but also to the policies adopted by the ABRC and SERC towards particle physics and astronomy in recent years. The latter resulted in the PPARC's inheriting a programme that it is unable to sustain, notably in the areas of particle physics and space research which involve ten-year timescales.

As an example, the CERN contribution requires £74 million in 1996–97, whereas the domestic funds available amount to about £27 million and have to cover research at CERN and elsewhere. A level of 50 per cent of the CERN subscription (£37 million) would be needed to allow the UK to contribute to the research in proportion to its share of CERN (presently 14 per cent).

The Particle Physics Committee submitted a programme to Council which is more modest but would require an extra £6.5 million per annum. The corresponding situation for astronomy is similar. Thus an overall increase of £10–12 million per annum (5–6 per cent) in PPARC resources would enable a reasonable scientific return to be obtained. The absence of any increase would mean that we are subsidising the research of other countries but failing to profit ourselves from the large outlay.

It should be further noted that, until about 10 years ago, increases in the contributions to international organisations caused by unfavourable changes in exchange rates (as opposed to changes in the volume of activity) were compensated by the Treasury. Since this practice was abandoned, the burden has fallen on the Science vote and has repeatedly caused difficulties.

Of the £12 million increase in the Science Vote for 1996–97, £10 million will be required to pay the extra costs of CERN and ESA. The fact that, under the current arrangements, this has to be shared by all the Research Councils is obviously not well accepted by those who do not use CERN or ESA. On the other hand, the government favours a low pound for economic reasons yet is unwilling to mitigate the negative effect that this has on science, which is increasingly international in cases where expensive facilities are needed.

I will now address the specific questions in your enquiry.

1. The large Hadron Collider (LHC) is accepted by the scientific community as the world's leading research tool for the future progress of particle physics. Very briefly, there is a remarkably successful theory known as the Standard Model that precisely describes the constituents of matter and the forces between them. It has one missing ingredient, the Higgs boson, which is needed to explain why things have mass. Without mass there would be no stars or planets and no life as we know it. The explanation of mass therefore seems of fundamental interest. General theoretical constraints show that the Higgs must lie within the discovery potential of the LHC, or that, should the theory be wrong, an alternative mechanism will be revealed. Not surprisingly, the LHC has attracted physicists from all over the world, not least from the USA, where the competing SSC accelerator project was recently cancelled. The USA and other leading countries (Canada, Japan, Russia) will all make substantial contributions to the LHC itself as well as to the experiments.

   Two complementary detectors (ATLAS) and CMS) are planned to search for the Higgs. Two are considered necessary to provide security against component failure that would take years to rectify. Both are universal in that they measure everything that happens simultaneously—thus both are very efficient, but use different technical solutions to detect the collision products.

   They have to work in a high-radiation environment which has necessitated several years of R & D in radiation hard detectors and electronics able to function reliably for ten years. Data rates are huge, corresponding, for example, to all the telephone conversations in the world. The impact in industry is non-negligible as they will have to supply the high technology needed and so profit from the experience of meeting the extreme requirements.

2. As things stand, UK physicists have leading roles in both ATLAS and CMS. This leadership is unlikely to be sustained if the UK is prevented by lack of funds from making its fair contribution to the resources needed. Inevitably, the choices would tend to be dominated by those countries able to make a proper contribution to the experiments. The failure to exploit the large intellectual imput to the R & D that UK physicists have made would reduce the prospects of British industry to receive orders for the high-tech components (which will amount to several hundred million pounds). It would also have a negative impact on UK science as a whole as the subject is known to be one that attracts young people into physics as a discipline.

3. The management of such huge projects as the LHC and its experiments is naturally very difficult but has been amazingly successful in the past. Both the accelerators and the detectors have been completed on time and within budget in contrast to several projects of comparable magnitude undertaken in the private sector. The LHC is larger than any of its predecessors and the experiments much larger and more difficult. ATLAS has 145 institutions from all over the world and over 1,500 physicists. CMS is only slightly smaller. As Chairman of the ATLAS Collaboration Board, I am part of the management structure. What makes the experiments work is the common desire to succeed against formidable technical challenges. This leads to effective collaboration with assignment of responsibility by consenus rather than through a hierarchical command structure. Resource management is controlled by representatives of the national funding agencies who allocate and monitor the use of funds within a total agreed in advance and rigorously enforced. Stability of funding is therefore an essential ingredient which, up till now, has been more or less honoured by all participants in large experiments, including the UK, albeit through sacrifices to the breadth of the research.

4. As far as particle physics is concerned, the PPARC is very effectively structured to carry out such research given adequate and reliable funding. The Particle Physics Committee determines funding allocations to experiments on an annual basis within a total allocation from the Council. The direct funds for experiments are managed through the Rutherford Appleton Laboratory under the control of a peer review committee which meets frequently.

   Grants are also made to the university groups and the Particle Physics Department at RAL to support manpower and infrastructure. This system has worked well for more than twenty years and has been refined to the maximum efficiency as a recent survey has shown. The system is envied by scientists from other countries.

In conclusion, I am certain that the LHC is one of the greatest and most challenging scientific endeavours ever undertaken, with a goal that is of fundamental interest to mankind—the origin of mass. It would be a serious loss to British science if the UK were not be be involved, or to to be crippled by wholly inadequate resources. There would be a corresponding loss of stimulation to potential young scientists. We hold leading positions in the experiments and the organisational structure of the PPARC would enable us to exploit that leadership very effectively, given a relatively modest increase in overall funding to the PPARC of 5-6 per cent, coupled with a policy to shield us from unfavourable exchange rate variations.

Professor T W B Kibble, Imperial College of Science, Technology and Medicine (9.12.95)

I am writing on behalf of the Theoretical Physics Group at Imperial College. This is a group of nine academic staff, one of the leading groups in the country working on theoretical high-energy particle physics (HEPP) and cosmology. Most of our support comes from PPARC, though we also have substantial European Community grants, and have received some funding from EPSRC.

Our research is motivated primarily by a wish to understand the structure and behaviour of the material universe at its most fundamental level. It is part of a long and proud tradition, an important part of our Western culture, particularly in Britain. The questions we are seeking to answer arouse very considerable interest among the general public, as evidenced by the sales of popular books such as Steven Weinberg's "The First Three Minutes" and Stephen Hawking's "A Brief History of Time"—or the many books of authors such as Paul Davies and John Barrow.

These are also the topics that often excite the interest of children and young people. Many of our students have been brought into science by these interests, though they often go on to work in other disciplines. Our students have demonstrated that the kind of training they receive provides an excellent background for work in many fields, from merchant banking to computer software.

Our theoretical work is based on the experimental results obtained by HEPP colleagues at laboratories such as CERN and on the work of observational astronomers using telescopes and satellite instruments. It is important that the UK should continue to play a full part in international collaborations in these fields. My comments here are mainly directed towards CERN, because that is the laboratory with which we have the closest connection. No doubt similar comments could be made about ESA, but our Group has not had much involvement with their work.

CERN is a prime example of truly successful European collaboration—antedating the formation of the European Community. It has become the premier HEPP laboratory in the world. Because of its success, this is one field where Europe has, in the last 20 years, established a clear lead, overtaking the United States. The UK has played a major part in this success, and continues to do so. CERN is not merely an experimental laboratory. It is also a leading centre for the theoretical HEPP research, with very wide influence through its programme of short-term visiting appointments. UK theorists are participating very fully.

It is impossible to predict what long-term applications might flow from such research, though history suggests there will be many. What is clear is that there are many important by-products. Instrumentation developed for HEPP has often found other applications. For example in our own Department work on silicon detectors for high-energy particles has led to a very successful collaboration with medical researchers on detectors for medical applications. Research in HEPP imposes exceptional demands on data handling, because we are searching for valuable nuggets amidst an avalanche of data. It is not surprising therefore that CERN has been one of the foremost centres for advanced computing and data handling. An interesting recent by-product was the World Wide Web, which has become the standard for communication of the internet; it was developed at CERN—incidentally by a British computer scientist, Timothy Berners-Lee.

At the present level of funding, UK scientists working in HEPP can still make good use of major international facilities such as the LHC at CERN. Indeed, UK scientists have played a very full role in the planning stages and are still doing so. A decision to withdraw from such an important project would be most regrettable. It is of course vital that the costs be kept under control. The UK's insistence on value for money has been, and continues to be, a very salutary influence on the CERN management. But it is equally important to maintain a balance between the cost of CERN and the remainder of the HEPP budget. The CERN subscription is already more than twice as large as the total grant allocation to university HEPP groups. It would not make sense to remain members of CERN while cutting the rest of the budget dramatically; we would then be paying to belong to a club we could not afford to use.

The UK is still one of the leading scientific nations in the world. We strongly believe that it is right and proper that such a nation should participate in collaborative international projects such as the LHC. By so doing we remain in contact with the forefront of scientific advance, and maintain a cadre of scientists trained to the highest levels and able to turn their talents and knowledge in many directions.

The structure of PPARC is well suited to its purpose. The managerial problems of "Big Science" are very different from those of most other sciences—the budget is dominated by international subscriptions, and the time scales involved are exceptionally long; it may take ten to fifteen years to design and build an experiment in HEPP, or to equip and launch a satellite. Long-term stability is absolutely vital if investment is not to be wasted. It makes sense for these problems to be handled by a separate Research Council, with a rather different mandate from the others. We support a continuation of essentially the present structure.

Letter to the Clerk of the Committee from Professor Graham Ross, University of Oxford (14.12.95)

I am writing in response to the call from the Science and Technology committee for written evidence about PPARC's work and in particular its participation in "Big Science". Let me first declare my interests. I am a theoretical physicist working on particle physics theory. Over the years I have been associated with the SERC and now with PPARC in many different ways, most recently as a senior Research Fellow. On the completion of this fellowship I returned to my position as University Professor. At present I am chairman of the theory committee which has the duty to advise PPARC on the management of and expenditure on theoretical particle physics research. However this letter is not written in my official capacity but as a member of the theoretical physics community working in a university environment.

PPARC was set up as the research council with responsibility for particle physics and astronomy research in the UK. It is my understanding that in the white paper covering the new research council structure it was acknowledged that "blue-skies" research is an appropriate and important area for government funding. As it was clearly impossible for the UK to fund all areas of "big-science" it was decided to concentrate on two areas at the centre of modern developments in the physical sciences in which the UK plays a leading role. Perhaps it is not necessary to repeat here all the reasons for such funding. The major goal is of course to probe the fundamental laws of nature. In this the scale of the research and the associated funding is dictated by the physics; for example it needs large accelerators to probe the distance scales relevant to the study of the structure of the atomic nucleus. A powerful argument in favour of such fundamental research is the need to foster the scientific culture in a country which relies on scientific products in almost all aspects of everyday life. In this is it essential to have an active ongoing research programme in such high profile subjects at the cutting edge of scientific research, not least to stimulate the young to an interest in science in general. It is worth noting in this context that other major nations such as Japan and China are actively building up their research effort in particle physics.

The European initiative to build a comon research facility to study particle physics has been spectacularly successful. CERN, the European high energy accelerator in Geneva, has provided the means by which European physics in this area has become the world leader in the field overtaking the historical dominance of the United States. The laboratory provides a European centre for physicists world-wide, both experimental and theoretical, to collaborate and exchange ideas. It is particularly valuable to the large number of young physicists who are able to develop their skills at the forefront of modern research. Their skills and the collaborations developed while at CERN provide crucial input to the national universities and research centres when they return home, enhancing the national science base.

The approval of the LHC project marks another important step in the programme to study the fundamental laws of nature. The energy and distance scales accessible to this accelerator offer the prospect of understanding important questions concerning the origin of mass and shedding light on the ultimate unification of the fundamental forces of nature including gravity. The decision to participate in this project ensures that the United Kingdom will retain its leading role in this area of research. However participation in such an international collaboration requires a strong national base if the facility is to be fully exploited. There is currently the danger that the squeeze on domestic funding, in part due to the increasing cost of maintaining a European collaboration in the face of a falling pound, will not allow adequate exploitation of CERN and the LHC. It is crucial that, once the decision to join the project has been taken, adequate funding for the domestic base must be provided to make use of the facility.

The management of a major international project such as the LHC at CERN is currently organised at several levels. The United Kingdom uses peer review for all projects involving local participation. This system works extremely well often resulting in improvements and cost savings as a result of the involvement of the external referees. It also ensures the best physics projects are chosen from competitive proposals. The peer review process is also used to run the experimental programme at CERN through committees composed of active physicists drawn from member states. Again this system works extremely well. Overall I think that the particle physics method of management is excellent and could be used as the model for management of other international projects. The funding of CERN however is not so satisfactory due to inadequate provisions for currency fluctuations. Over the years the need to fund the CERN contribution, payable in Swiss francs, has often resulted in drastic reductions in the domestic science budget not confined just to particle physics. This is clearly not the way to manage a sensible science programme and I feel that funding of all international projects should be fully protected against currency fluctuations.

PPARC's management is broadly based on a two tier structure. The PPARC committee has the ultimate decision making responsibility. It is advised on the particle physics side by the Particle Physics committee and by the Theory committee. These latter committees have the responsibility for funding the experimental and theoretical research projects and also advise on the general direction of the subject. As mentioned above the peer review system works very well. However the communication between the PPARC committee and the other committee could easily be improved by appointing the chairman of the Particle Physics committee to be, ex officio, a member of PPARC.

I turn now to the role of PPARC in funding particle physics research in universities. I have already commented on the merits of "big science" research in the United Kingdom but it may be of interest to put this in the local context. In the physics course at Oxford University the astrophysics and particle physics options are extremely popular, stimulating the student's imagination. Indeed when students applying to come to Oxford are asked why they chose physics very often they reply that it is as a result of reading about developments in astrophysics and particle physics. The interest extends beyond the undergraduate level; in theoretical physics there are usually some 70 applicants wishing to study for the D.Phil. in particle physics for just two PPARC funded studentships. The quality of these applicants is extremely high; almost all are predicted to get first class honours. At the postdoctoral level too the desire to study particle physics is very strong; we have typically some 150 applicants for two PPARC funded fellowships. These young postdoctoral fellows provide a high quality pool of talented people who help maintain the standard of academic life in this country. However more start to study the field than can be absorbed in the academic community and many leave to work in a variety of disciplines. In my experience the skill acquired in studying particle physics are valued by prospective employers. The ability to "problem solve" is of use in many diverse areas as are the mathematical and computing skills that are a necessary ingredient of the modern training of a particle physicist.

Overall I think that PPARC's management of theoretical particle physics research has been very successful. By any measure such as publications, invited rapporteur talks at international conferences etc. United Kingdom theorists are playing a major role world-wide in the development of the subject. Their work has been vital to the exploitation of the results obtained by the large accelerators such as LEP. They are also providing essential training in the mathematical sciences for young scientists at undergraduate and graduate level.

I hope these comments will be of help to the committee.

Letter to the Clerk of the Committee from Professor P V Landshoff, University of Cambridge (12.12.95)

I write on behalf of the elementary particle physics group in this department in connection with the review of the Particle Physics and Astronomy Research Council.

We are theoretical physicists, but we could not continue our research without interaction with a vigorous community of experimentalists. It is of importance to all UK particle physicists that the experimental programme should continue at least at its present level. Existing facilities will continue to produce useful results for the next few years, but the Large Hadron Collider will be essential to answer the fundamental questions that have arisen from previous research and to keep up the interest in the subject. The LHC will enable the UK to continue to be one of the world leaders in an area of physics which is important not just for its own sake, but also because of the interest and stimulus it gives to incoming students. Many of these, while they have been attracted to physics through an interest in particle physics, go on to do other things, not necessarily even within science, but take with them valuable enthusiasm and expertise.

We believe that PPARC has set up a good structure. It gives a great deal of attention to both informing and consulting the community of physicists, and therefore to putting itself in the best position to take wise decisions. We do regret, though, that it has been forced to reduce its grants for travel: these are important for theorists if we are to be able to meet our colleagues, both theoretical and experimental. Such interactions are essential to generate ideas and keep us all up-to-date.

Memorandum submitted by Department of Physics and Astronomy University College London (13.12.95)

1. Background

University College London is the leading recipient of PPARC grant funds in the UK and the Department of Physics and Astronomy has a major representation in both particle physics and astronomy/astrophysics. Staff have been, and continue to be, involved in important discoveries in both fields and occupy senior positions on PPARC committees. Current responsibilities include chairmanships of the Astronomy Committee, the Astronomy Theory Committee and the Particle Physics Experiment Selection Panel, together with membership of several other PPARC committees and panels.

2. How important is it that the UK continues to participate in "big science" projects such as the LHC?

"Big science" is big because the questions it asks are big; they go to the ultimate boundaries of human knowledge. However, the expression is used in practice about particle physics and astronomy because (in the minds of other scientific disciplines) the field involves large capital expenditure projects, and substantial international subscriptions to major facilities and agencies. Other fields in fact do have larger volumes of annual expenditure (eg EPSRC, BBSRC), but is distributed over large numbers of university laboratories and UK-based facilities (eg the large numbers of NMRs in laboratories around the counrty). Individual physics and astronomy departments do not need (or have) their own telescopes/satellites/accelerators—rather they use centrally provided facilities. The same is true worldwide.

As facilities became too expensive for individual national budgets, our membership of international organisations such as CERN, ESA and overseas ground-based observatories has given us direct participation and leadership in major discoveries which have rebuilt the picture of the fundamental forces of nature and our view of the universe. For example, access to regions of the spectrum inaccessible from the ground (eg x-rays and the ultraviolet) can only be studied using satellites, which emphasises the importance of involvement in and exploitation of ESA.

It should be noted that all the facilities that the UK is involved with are internationally funded—ie other countries do want to be associated with them, and find the necessary resources to participate. UK scientists in "big science" cannot continue effectively in the international arena, or in competition with overseas scientists, without access to these major organisations and facilities, future upgrades of these and new initiatives.

Particle physics, astronomy and their joint offspring—cosmology—also provide many of the ideas and projects which catch young people's imagination and turn them to science. "Big Science" in the UK continues to attract the highest quality undergraduate and postgraduate students, who "vote with their feet" in choosing the fields of study that motivates and stimulates them. These fields thus provide an important training ground at the cutting-edge of science and technology for the UK's future generations of scientists, engineers, managers etc.

Since Newton and the foundation of the Royal Society, UK scientists have been a major force in forming the picture of the natural world and extending the boundaries of knowledge. Many of the important questions in contemporary particle physics and astronomy have been posed by UK scientists and some of the greatest experimental and observational achievements since the second world war have had strong UK input. Withdrawal from participation in the world's most ambitious programmes would close down one of the most vital components of our nation's intellectual life.

3. Are UK scientists able to exploit this type of collaborative facility?

For astronomy, the answer is at present "yes", both intellectually and (currently) by responsive grants from PPARC. The grants are primarily used for (a) PDRA and PhD manpower for data exploitation and training, and (b) instrumentation grants for facility updates, and to instrument ESA satellites. However, continuing financial pressure on PPARC (generally on an annual basis) impacts severely on the domestic resources available for grants to university groups (for data exploitation and instrumentation). It is therefore crucial that PPARC properly manage the overall programme to ensure the correct balance between facilities (space and overseas observatories), UK-based (support) establishments, and responsive grants which cover the main PPARC expenditure lines.

In this context, the Prior Options Review of the RGO/ROE is crucial. The recent changes in management and financial autonomy given to the LPO, Hawaii, which has long been in place for the AAO, is to be welcomed. Less convincing is the subsequent continued need for significant expenditure at the UK-based RGO/ROE establishments.

In particle physics, the answer is also "yes—so far". Most major experiments at CERN have a strong UK presence, and large parts of the activity are led by UK scientists—up to the present Director General. The "so far" qualification comes because of the split nature of the funding. The CERN subscription is fixed by treaty and paid in Swiss Francs, so that a weakening pound means a steady rise in this amount, financed from the Science vote. This generates inevitable, and wholly destructive, pressures for matching reductions in the so-called domestic resources devoted by UK-based scientists to building and analysing experiments—mostly at CERN. It has sometimes been embarrassing in recent years to see the UK fail to participate fully in inexpensive but scientifically crucial parts of the programme because the UK groups could not finance equipment—or even send enough people—to contribute to active experiments and capitalise on the subscription.

The situation is similar in astronomy in relation to the ESA subscription. It makes no sense for the UK to pay a substantial annual subscription, if it does not retain sufficient domestic resources to exploit that through both instrumentation budgets and data exploitation lines. The recent ESA agreement (which will reduce the Science subscription by about 15 per cent over 3 years) is excellent, but will only be so if the monies saved can be ring-fenced to allow for improved ESA exploitation. For some years the ratio of Domestic Space/ESA Subscription spend in the UK has been by far the lowest of all ESA member states (and falling steadily), which has hampered our ability to properly exploit ESA. This should improve over the next few years *if* the ring-fencing noted above is secured.

It is worth noting that the UK is the *only* country which finances its subscriptions to CERN and ESA via the science agency (PPARC) and this has been very detrimental to programmes in the past. There can be little doubt that a return to the approach of Treasury funding for international subscriptions would be scientifically beneficial.

4. How should major international projects be managed and funded?

In astronomy, the present system works reasonably well. However, better use could be made of the expertise that exists in major university groups in instrumentation development and management. The DRAL has good record in the overall management of major capital projects in recent years (examples from astronomy are: JCMT, SOHO-CLUSTER and ISO), and PPARC should continue to buy in this expertise when appropriate. The crucial thing is (a) to secure reliable and accurate cost-to-completions at the approval stage, (b) stick firmly with that c.t.c., (c) descope as necessary if cost overruns are identified downstream. In that way, PPARC can effectively manage its overall portfolio of capital projects, without damaging grant exploitation lines.

In particular physics, the CERN model has much to recommend it. The Director General is answerable to a Council, which has both Government and Scientific Members, sitting in national delegations. He has recently been given authorisation to negotiate with non-member states on new forms of associated membership in order to turn the LHC into a truly world project. The Abragam committee looked very hard at the whole administrative structure at CERN and found it largely sound.

Other management models for particle physics are the national laboratories such as DESY in Hamburg, or SLAC and Fermilab in the USA. There, local managements negotiate terms of entry for overseas participants in the programme. UK groups have usually found these satisfactory.

The OECD Megascience Forum is going to be more involved in the setting up of International Laboratories in the future. We feel that they should have much more direct input from experienced scientists than they have so far invited. For example, scientific bodies such as ECFA and ICFA exist to form responsible regional and world policies on future developments in accelerators and would be very willing to cooperate in strategic planning.

5. PPARC's MANAGEMENT OF ITS PORTFOLIO.

Given the fact that PPARC has only recently come into being, and is still evolving, it is a bit early to criticise. The initial transition to PPARC has been smooth, with a working structure of peer review and policy formation inherited from SERC. However, there is more central control at Swindon (both for policy and executive functions) and we have yet to see the full consequences of the changes which have been made in the lines of managerial responsibility. It is important that PPARC staff (at Swindon) have a good knowledge of the fields they are serving, but this is often not the case. It is crucial that proper peer review, both at the grants level and in policy making at Council and committee level is maintained.

The PPARC chief executive and programme director now have direct responsibility for final decisions and for presenting programmes to Council. This could be a retrograde step since they are not directly involved in the peer review process in which priorities are fixed, and their presentation may not have the authority which used to be carried by the chairs of the former senior SERC committees for astronomy and particle physics, such as the Nuclear Physics Board. Neither have we yet seen the new relationship with the Rutherford Appleton Laboratory will work. They had an excellent track record in controlling and managing programmes on behalf of the user community. There are fears that Swindon might be tempted to set up an expensive and inexpert parallel administration to second-guess the mechanisms which have worked so well in the past, for example in the setting up of LEP and HERA experiments at DESY.

Letter to the Clerk of the Committee from Dr P A Charles, University of Oxford (13.12.95)

Given the seemingly endless reviews of various aspects of UK astronomical research that have taken (are taking) place in the last two years, it would seem at first sight that another one is the last thing that we need. However, with a review of PPARC itself, we welcome the opportunity to examine more fundamental problems with the way that basic science is supported.

1. We believe that your investigation cannot fail to see what is really behind the problems that we are facing now. As with most aspects of UK science our budget in real terms have been under substantial pressure for some time. But what has made it much worse is the effect of annual variations in the international subscriptions. With the combined ESA and CERN subscriptions now accounting for over 50 per cent of the total PPARC budget, quite small currency fluctations can bring about drastic effects on the funds that are available for the domestic programme (and that is after account is taken of the arrangements that were put in place to supposedly prevent this problem occurring!). This is made worse by the long-term nature of the astronomy and particle physics projects that are undertaken now and which cannot easily absorb year to year fluctuations. Experiments and telescopes cannot be easily chopped around and moved about. They are decade-level investments and must be seen as such from the beginning.

We are the only European country that operates its domestic science program under such circumstances. So far, we have succeeded in using our modest funding most effectively compared perhaps with more lavishly supported projects elsewhere, but the end of this approach is clearly in sight. Without effective protection from annual fluctuations, our domestic program will suffer major, probably irrevocable damage. Having built up a reputation in ground-based astronomy second only to the US this would be an enormous shame. Our success in this area (Anglo-Australian Telescope, UK Infra-Red Telescope on Hawaii, Isaac Newton Group of Telescopss on La Palma) has provided a series of high profile accomplishments that stimulate interest in science in the wider sense, and is especially influential at a time when science enrolment at schools and universities seems to be falling.

What is the solution? Simple! Remove the subscriptions from the science budget (in any case they are largely now a political contribution, and are more than recovered by ESA/CERN contracts placed with UK companies!) and transfer them to the Foreign Office.

2. On the matter of the Observatories themselves, I must raise the very serious concern about PPARC's overall management policy. In spite of several (major) reviews of their activities over the last 10 years, SERC and now PPARC cannot make up their mind over how they are to operate. The 1987 review and its decision to move RGO (from Herstmonceux to Cambridge) was very damaging to morale, but at least it was hoped that it would put an end to uncertainty for a while. Not a bit of it (and really not surprisingly, given that we were still left with two smallish institutes operating in closely related areas but geographically very

separated!). In 1992, all the observatories (overseas sites plus RGO plus ROE) were placed under the control of a "super-director" and an umbrella "Royal Observatories" organisaiton created. This was certainly not a success, with inter-site friction reaching new levels, followed by even further loss of morale. And now, as of two months ago, PPARC has disbanded the Royal Observatories structure, leaving all the sites independent of each other, but reporting direct to Swindon. Such continual chopping and changing of the organisation almost beggars belief in terms of wasted time, effort and money.

What is the solution? We are participating (with Cambridge, Durham and other astronomically active UK universities) in a bid to set up an organisation which is run by the universities and which will take on the responsibility from PPARC of operating the UK-based "astronomical technology centre". The overseas sites (in La Palma and Hawaii) should operate much more closely to the AAT model in which they have guaranteed budgets and much greater independence from Swindon. We believe that the AAT is so successful precisely because it has such independence!

3. A frequently asked question about the PPARC committees (as it was of those of SERC) concerned how representative they were of the community they were serving. How were the members chosen? Who dictates the key policy directives that are given to the committees and which so profoundly influence long-term funding decisions? This whole process needs to be much more open (and acountable?)!

There are those within PPARC who would say that many of the current problems were not "their fault", but were simply inherited from SERC and they have had insufficient time to make major changes. I think most of us feel this to be disingenuous. The name may be different, but the people involved are largely the same, and it is already obvious that PPARC is remarkably similar to its predecessor.

Letter to the Clerk of the Committee from Sir David Cooksey (13.12.95)

I was a Council member of PPARC from its inception until I resigned earlier this year.

I welcome your inquiry into PPARC because of the virtually impossible constraints under which it operates.

As you identify in the Notice of the Inquiry, PPARC allocates 54 per cent of its expenditure to two international agencies, the European Space Agency and CERN. In addition large parts of the residue is committed to large international collaborative efforts in ground based astronomy. This results in a very small proportion of the total expenditure being subject to the discretion of PPARC itself. That is dangerous because uncontrolled changes in the demands by these agencies severely restrict the capacity of PPARC to support other basic science in the UK. This results in short-term instability whereas a long-term view is vital.

The true position is even worse, because the Council of PPARC has been pre-empted by the DGRC in negotiations with ESA and CERN and by the ordering of a Prior Options Review, by his department, of the ground based astronomy operations. And he appears to take the key decisions independently of PPARC, so that the PPARC Council is an entity operating only at the periphery of the science budget for which it is supposed to be responsible and accountable.

I have never needed to be a mere rubber stamp for decisions taken by others. I, therefore, resigned from PPARC so that I could devote my efforts to more productive ends. I was originally persuaded to join PPARC because I believe in the stimulus to learning provided by such fundamental science. Astronomy is one of the few routes that appeal to young physicists to continue their studies in physics.

The value of PPARC can only be delivered if it is given the flexibility to plan its future fully insulated from the impact of the increased funding demands from international agency subscriptions (not merely from the foreign exchange effect). The international subscription budget should be separated from the funding of UK based science. PPARC should be given the freedom to plan for itself how it will deploy its resources over a reasonable forward timespan. This is funding for long term research which must not be turned on and off by external influences outside the control of PPARC.

Government has to make the choice of either having a single central research council which takes all of the decisions, or it can choose to disperse funds to a number of autonomous research councils which are empowered to allocate those funds as they see fit. Government is fortunate in being able to call on the services of able and dedicated people to serve on the research councils. They will not remain so well disposed if authority, responsibility and accountability are not properly delegated to them.

Letter to the Clerk of the Committee from Sir Francis Graham-Smith, Nuffield Radio Astronomy Laboratories (14.12.95)

The Science and Technology Committee has identified PPARC's international commitments as a key element in scientific and funding priorities, noting that ESA and CERN together account for 54 per cent of PPARC's total expenditure. This is by all accounts far too large a proportion, with serious effects on the funding of the university research which these itnstitutions are intended to support. The most obvious and all-too-frequent effect is the cut in funds which inevitably follows a variation in exchange rates.

I am confident that the Committee will appreciate the importance of collaboration in international science, whether it be in the spectacular fields of space research or in the quiet confirmation of partnerships with astronomy in South Africa. I would like the Committee to be aware that all research in our fields is very largely international, and the very real advantages of international research are fostered at least as much through the individual university research groups as through the large institutions. It is these groups that establish the excellent reputation of UK science.

My experience in astronomy spans both optical and radio. Simple examples of international collaboration will be familiar to any active research astronomer; in my field of pulsars I would point to the joint programme between Jodrell Bank and Australia, which has led to the discovery of two thirds of the present catalogue of 700 pulsars; further, the catalogue itself has a third author, in USA, and there is an active European collaboration in the subject funded by the European Commission.

On the broader scale the overseas optical observatories such as La Palma are run directly as an international collaboration, but without the overhead costs of an actual institution. Here the observatory itself is the tip of a pyramid, with the many participating university research groups as the base. Less visible but equally important examples are the radio interferometer networks, comprising the international scale VLBI and its European subset EVN; and the complementary 200 km scale MERLIN; these provide an essential service to astronomers throughout the world without even requiring any secretarial services outside the participating radio observatories themselves. In all these examples, but in VLBI and EVN in particular, the organisation is efficient, economic, unobtrusive, and self-regulating, while the facilities provide for front-line research in all four university groups.

The value of the international element in these various examples is surely at least as great as that of the more obvious collaborations In ESA and CERN. It is at least unfortunate, and in some cases disastrous, that funding for excellent science in the UK research groups is perpetually under the shadow of funding for these institutions. The result has been that the system of peer review leading to reasonable decisions on priorities has been eroded, with the exigiencies of financial constraints over-riding the normal processes based on scientific criteria.

I hope these remarks will be useful to the Committee, and I would be glad to give any further assistance.

Letter to the Clerk of the Committee from The Society of British Aerospace Companies Ltd (12.12.95)

Press Notice No 15 dated 19 October invited views on the operation of the Particle Physics & Astronomy Research Council (PP&ARC). Whilst welcoming any move to improve the effectiveness of public funding in research, we are concerned that the Science & Research Committee should take into account the wider implications of research as an investment for the long term, national benefit.

As a leading edge technology industry, the aerospace sector is a strong supporter of curiosity driven research. All too often, other nations have benefited commercially more strongly from our research efforts than has the UK, by investing in the exploitation of our inventiveness. Since the level of future investment in research by the public and private sectors is directly proportional to the vitality of our economy, we clearly need to improve our ability to achieve a return in the national funding (private & public) of UK research.

The recent Technology Foresight Panel reports identified the national spend on research as having a major potential for wealth creation and made recommendations on how this potential might be fulfilled. Indeed, the Science & Technology Committee report on Foresight stated that "much publicly funded research should be directed to topics where industry might have an interest" and that industry's willingness to implement Foresight recommendations "might be undermined if Government is not seen to be allocating the resources to ensure that the programme is a success". SBAC members welcomed the Foresight reports and have responded with an initiative, entitled Foresight Action, designed to provide the means for maximising wealth creation from research investment in our sector. However, the successful implementation of Foresight Action will require a meaningful investment partnership between industry and Government as envisaged by the Science & Technology Committee.

We believe, therefore, that the Science & Technology Committee should address PP&ARC funding issues within the wider context of whether we as a nation have got the balance right between our investments in "big science" and wealth generating research. The UK's technology based industries are facing unprecedented challenges from traditional and emerging competitor nations; nowhere is this more keenly felt than in aerospace which has been identified as a strategically important industry by all our competitors. The loss of a capable aerospace sector would have serious implications for the UK's balance of payments and, ultimately, the nation's ability to invest in all types of research.

In summary, the questions posed by the Science & Technology Committee begs a much bigger question which must be asked before getting into the detail of PP&ARC priorities and modalities. We believe the logic contained in the Technology Foresight reports must pervade any debate on research funding. There is a crucially important case to be put to the Committee along these lines to aid them in their deliberations, and we would welcome the opportunity to present it.

Letter to the Clerk of the Committee from Carlos Morgado (11.12.95)

I am writing in response to your call for comments on the work of the Particle Physics and Astronomy Research Council. I studied for my PhD in Particle Physics at the University of Bristol and on completing my thesis, took up a position as Research Associate with the HEP group to work on several experiments. I have recently made the rather difficult decision to leave research and take up employment in private industry. The reasons that led me to make this decision are, I feel, relevant to your enquiry and hence I would like to bring them to your attention.

The general funding situation for Particle Physics seems to me to be at best precarious and at worst suicidal. Over the last decade there have been constant problems with funding for HEP experiments. In the last couple of years the seriousness of this situation has led me to reconsider my career path. The constant cutbacks in funding and the general atmosphere which the government's attitude to HEP has generated, has left many members of the community, myself included, wondering if there is a future for HEP in the UK.

I made the decision some time ago that since I am not interested in teaching I would not apply for a post as a Lecturer when my period as a Research Associate expired. I feel it would be be very hypocritical to take up such a position purely for the sake of improving my career security. Having made that decision I have come to realise that my career progression is very limited. Staying on and progressing to Research Fellow simply moves me onto a different salary scale, it does not bring with it the equivalent opportunities that are implicit in appointment as a Lecturer. My opportunities for project management would be minimal, certainly not reaching the levels of responsibility which I would hope to one day achieve.

The lack of funding for training results in people like myself having to be self taught. This attitude is in general applauded but it does lead to sub standard techniques and low efficiency. The lack of funding for the purchase of up to date laboratory equipment has made my work very difficult at times. Using outdated equipment is frustrating, inefficient and at times stops research work for long periods of time.

I sincerely hope that my experience and those of my colleagues are taken into consideration and that the government takes a fresh look at the way in which it handles HEP.

Letter to the Clerk of the Committee from Dr J V Wall, Royal Greenwich Observatory (15.12.95)

The Particle Physics and Astronomy Research Council finds a large and increasing proportion of its funding being committed to the UK subscriptions to two international organisations, the particle physics research laboratory CERN and the European Space Agency ESA. Recent arrangements—in which increases in these subscriptions are spread across the Research Councils—have partly alleviated this problem, but even small percentage increases in these subscriptions continue to have a disproportionately high impact on the domestic sector of the PPARC programme.

Within an overall budget that is declining slightly in real terms, these subscriptions are rising in real terms. The domestic programme thus provides the balancing line in the budget, and stability, ability to plan, and our capacity fully to participate in our international partnerships is severely compromised. One consequence has been that UK university-based space research groups have been increasingly unable to exploit our membership of ESA.

The long-term impact on the ground-based astronomy programme is particularly worrying. The cost of the UK's ground-based telescopes is relatively low, yet the scientific output of these facilities is very high. In a recent US survey of the world's most-cited publicatons in astronomy (*ScienceWatch* June 1993), the international standing of UK astronomy was evident—no less than eight of the top 20 papers were based wholly or in part on data gathered by PPARC's ground-based astronomy facilities.

Naturally, there needs to be a balance between ground-based and space research. But bearing in mind that the UK aerospace industry benefits from UK membership of ESA through the principle of *juste retour*, gaining its share of high technology contracts, it might be more appropriate for eg the Department of Trade and Industry to take responsibility for ESA subscriptions; the advantage for PPARC would be a stable, albeit smaller, budget for its research programme.

From the point of view of the Royal Observatories, who are responsible for the operation of most of PPARC's ground-based facilities, this stability would be particularly welcome. In recent years the Royal Observatories have undergone a series of reviews and reorganisations which have as yet had no conclusive outcome and which have led in turn to the present Prior Options review. Stability of funding and organisation for the Royal Observatories, perhaps in a new relationshhip with the Research Councils, should be a high priority in order to avoid disruption to the ground-based programme.

I would welcome the opportunity to provide further information on the Royal Greenwich Observatory's view of a future which addresses these matters and allows the full exploitation of the UK's vigorous astronomical community. This community, of which the Royal Observatories are a significant part, has enormous potential to steer the ablest young students towards science and wealth-creating technology.

Letter to the Clerk of the Committee from Professor A Donnachie, University of Manchester (13.12.95)

I am writing to you in my personal capacity as a particle physicist, and as someone with recent experience of the SERC and CERN. I was a member of SERC from 1989 to 1994, Chairman of the Nuclear Physics Board from 1989 to 1993, Vice-Chairman of the PSA Board throughout its brief life, and UK Scientific Delegate to the CERN Council from 1989 to 1994. At CERN I was Chairman of the Super Proton Synchrotron and LEAR Committee from 1988 to 1992, a member of the Scientific Policy Committee from 1989 to 1992 and a member of the Research Board from 1988 to 1995. In addition I served as one of the four scientific advisors to the OECD Megascience Forum in 1994.

The prime purpose of particle physics is intellectual. There have been many valuable spin-offs, ranging from synchrotron radiation and neutron spallation sources to the World Wide Web, but these are serendipitous and are not the *raison d'être* of the subject. The intellectual motivation is to probe the ultimate constituents of matter on the smallest possible scale to tackle the question of the origin of the Universe. Astronomical observations all imply that the Universe is still expanding from an exceptionally dense and energetic state immediately following the "big-bang". The collisions of particles in modern high-energy accelerators recreate fleetingly the conditions and the subatomic particles (the ultimate constituents of matter) which existed in the first fractions of a second after the big-bang. Travelling back in time in this way, some 15 billion years, complements astronomical research which can study the early condition of the universe by exploring the furthest regions of space. Studying matter on the smallest scale is now inextricably linked with research on the largest scale, and together they map the development of the Universe from its earliest beginnings to the present day.

As accelerator energies increase the accessible scale decreases and we automatically move further and further back in time. For more than forty years particle physics in Europe has been a co-operative venture, centred on CERN, the European Laboratory for Particle Physics in Geneva. The next major project for CERN is the Large Hadron Collider (LHC) which will reach energies 10 times greater than the highest currently available. This project was seen by all members of CERN Council, including the UK, as being the essential next step for particle physics not only in the European context but also on the world scene.

In the context of both my UK and CERN committee memberships I was closely involved in the discussions and negoitiations prior to the approval of the LHC in 1994. The UK, in partnership with Germany, insisted on the project being contained within a reducing CERN budget as a condition of our participation and this was ultimately accepted by CERN Council. It is important to note that this is a continuation of a long term trend. The CERN budget has been decreaing steadily in real terms (measured in Swiss Francs) for some 15 years, alleviated only slightly by the accession of new member states.

CERN is now recognised as the world's leading particle physics laboratory. Although evidence for this had been visible for some time prior to the event, the real breakthrough came with the construction of the proton-antiproton collider and the discovery of the $W\pm$ and Z^0 bosons in 1982. This project, brilliantly conceived and executed, revolutionised the subject and earned Rubbia and van der Meer the Nobel prize, the former for the physics and the latter for the technology which made it possible. This was followed by the highly successful electron-positron collider, LEP, consolidating CERN's position. The emergence of Europe as the lead player, with CERN at the forefront, is well documented by the changing pattern of physicist movement. At one time dominated by movement from Europe to the USA, it is now been completely reversed. In addition the two main experimental proposals for the LHC programme have attracted participants from more than 30 countries.

In recognition of CERN's standing as a world centre, steps have been taken by CERN Council to facilitate formal participation by non-European states for the LHC era. My understanding of the present CERN Convention is that full membership is open only to European states, but that some form of associated membership is possible for major participants. This carries with it a financial obligation, and the first significant development has been the payment to CERN of 5B Yen from Japan. The UK was extremely helpful to CERN and Canada, to provide pro rata contributions. Unfortunately these have been more protracted than initially anticipated. In my view this a direct consequence of the delay in LHC approval consequent on the stance taken by the UK and German Governments. Following the Drell report on the course of action to be adopted by US particle physicists after the termination of their Super-Conducting Collider project, the impetus for an agreement between the USA and CERN was strong. However this dwindled with the delay in LHC approval and the results of the 1994 Congressional and Senate elections appear to have induced further delay. A somewhat similar situation holds with Canada. It is to be hoped that these negotiations will be successful in the end.

CERN has an unsurpassed record of achievement in accelerator construction. I have already mentioned the proton-antiproton collider which revolutionised accelerator technology. Prior to that CERN constructed the world's first proton-proton collider, the Inter-secting Storage Rings (ISR) and subsequently LEP, the world's highest energy electron-positron collider. CERN has been able to achieve this within a declining budget by extensive re-use of facilities, The proton synchrotron (PS) was CERN's first accelerator and has remained in use as part of the injection system for the newer machines. It will continue to serve the LHC. The SPS was converted to operate as the proton-antiproton collider, and is once again a stand-alone machine but is used also as part of the injection cycle for LEP and will perform the same function for the LHC. CERN also has an excellent record of prioritising its scientific programme, closing accelerators as required to ensure proper support for its front line facilities, The ISR was closed in favour of LEP, and now LEAR (low energy antiproton ring, a unique facility) will be closed in favour of LHC and the SPS programme severely curtailed for the same purpose. The latter has to be maintained at some level as it supplies a variety of test beams which are essential for the development of new detector technologies and for testing new detector modules before final installation. LEP will run only until the end of the decade and then terminate in favour of the LHC.

United Kingdom particle physicists have long had a reputation for excellence in the field, and our *modus operandi* of strong university groups in collaboration with the advanced technological capabilities of the Rutherford Appleton Laboratory is the envy of many. The quality of our particle physicists is attested to by the key positions they occupy in major experiments and CERN committees, and it is notable that both the CERN Director General and the leader of the LHC project are UK nationals. PPARC is functioning well and is clearly capable of dealing efficiently with its research portfolio given adequate resource. It has been explicitly demonstrated in run up to the LHC approval that the CERN budget can be, and is, firmly under the control of the member states.

The problem which faces UK particle physicists is that of inadequate domestic funding to provide support of our experimental programme commensurate with our contribution to CERN. The domestic spend is being forced down by an increasing contribution to the CERN budget, even although the latter is decreasing in real (Swiss franc) terms. In principle the methodology of calculating the annual contribution to CERN should automatically compensate for fluctuations in exchange rate. In practice this is not operating for two reasons. One is that the Swiss franc has strengthened against a basket of currencies, not simply against sterling. The other is that the German contribution has reached its ceiling, so that the brunt of exchange rate changes is borne by the UK, France and Italy. The situation has been exacerbated by the agreement reached, with UK connivance, at the time of approval of the LHC project to reduce the ceiling for any member state from 25 per cent to 22.5 per cent.

Stability of funding is essential when operating on the timescales of particle physics. For a project like LHC the timescales are: five years from initial design concept to approval; 10 years from approval to completion of accelerator and detectors; and a further 10 to 15 years for exploitation. Within the context of the present CERN convention it is not obvious how one can guarantee a stable contribution for any given member state even with a stable CERN budget in Swiss francs. From a member state's viewpoint, the best way to manage a major international project is to agree a definite contribution in one's own currency. From the organisation's viewpoint it is better to have the budget based on the local currency, particularly when it is a strong one. Resolving this potential conflict of interest is central to the continued health of CERN, and to that of UK particle physics. Without our CERN membership we would cease to be major players in particle physics.

Letter to the Clerk of the Committee from Matra Marconi Space Ltd (15.12.95)

Matra Marconi Space (UK) welcomes this opportunity to provide written evidence to the Science and Technology Committee about the space science aspects of PPARC's responsibilities, which directly affect the market in which MMS operates. As the largest space company operating in the UK MMS has benefited from the UK's active and enthusiastic support to the European space effort which provided the foundation of the European space industry, and to a lesser extent from the national programmes that together account for PPARC's (and its predecessor councils) activities in space science.

A major commitment on the PPARC budget is the subscription to the mandatory ESA Space science programme. It should be recognised that this subscription does not merely provide the UK science community with access to ESA missions, the majority of this money flows back into UK industry. The following major benefits arise from such a flowback, as a direct result of the subscription:

- The ESA long term Science programme (called Horizon 2000 and its proposed successor Horizon 2000+) makes up 10 per cent of the overall ESA budget, but typically represents 30 per cent of the annual UK funding into ESA. The predictable and stable nature of this programme enables industry to make strategic investment in people, facilities and research and development projects. These resources are then available for deployment on other programmes including commercial projects.
- The quality of the Science programme facilitates the recruiting and retention of high quality staff. Motivated and experienced staff are a key resource for exploitation of future application programmes.
- Leading edge technology is developed on science projects. In conjunction with the ESA Technology Research Programme (TRP) and with industrial investment in R&D, these technologies and techniques can be exploited in commercial programmes.
- The European space industry has matured under ESA programmes and is now capable of competing in the international market. The Science programme has thus facilitated European collaboration and continues to sustain co-operation.

Thus it can be shown that the ESA Science programme, funded by the PPARC subscription, has a disproportionately large benefit to UK industry, considering its relatively modest percentage of the overall ESA budget.

When considering the best use of limited resources, the cost effectiveness of international collaborative Agencies such as ESA must properly be questioned and examined, and MMS supports the need for ESA and European industry to become more efficient. UK industry is fully motivated to be competitive to access the wider international, mainly commercial, markets. MMS considers that the best way to bring about such efficiency gains is to continue to work with ESA, and to use the considerable influence and reputation that the UK has built up within the wider European science community. In order to maintain that influence, built on scientific excellence, it is necessary not only to contribute in full to the ESA programme, but additionally to have a balanced national programme to enable UK scientists to collaborate fully in the exploitation of the ESA Space science projects. The current difficulties experienced by PPARC in maintaining the national programme is therefore of some concern to MMS. The relatively modest additional amounts required to enable PPARC to fund the UK space science community activities will allow the UK to maintain its pre-eminence in this field, and continue to enjoy a disproportionately large influence on future scientific missions. It is important that this issue is addressed now, in order to ensure the continuity of science data from future missions.

Other aspects of the science programme that are beneficial to the space industry without being directly connected include:

— The ESA science programme is internationally recognised for its scientific excellence and comparative cost effectiveness. A particular advantage in comparison with the NASA programme is its stability and freedom from annual fiscal interference. Through membership of ESA the UK is able to participate in ambitious science projects that could not be afforded nationally. The positive publicity that surrounds Horizon 2000 missions raises the public awareness of, and support for, science.

— UK scientists gain proportionately greater access to science opportunities and science data than the UK percentage subscription level would indicate—the UK gets good scientific return for its investment.

— The infrastructure costs such as ground control and test facilities of ESA science missions are shared with other programmes, increasing usage and efficiency.

— The UK is committed to pursue its space policy through ESA. The UK should therefore fully support the mandatory space science programme to ensure that this commitment can be fully exploited by industry and others.

The formation of PPARC itself is welcomed, as is the establishment of PPARC's Industrial Liaison Policy/Advisory Committee; the latter providing a very effective forum by which to progress PPARC/industrial collaboration to the benefit of the community as a whole. It is however extremely important that PPARC, as a partner in BNSC, acknowledges the strategic significance of the ESA science contribution within the wider context of the UK's policy towards ESA as a whole, and its key role in the industrial exploitation of ESA programmes. It is hoped that the consolidation of UK civil space interests under the DTI will help further this co-ordination.

Letter to the Clerk of the Committee from Professor Susan Cooper, University of Oxford (12.12.95)

This letter is in response to the Press Notice inviting comments on PPARC. I have recently joined the University of Oxford as Professor in the area of particle physics, having spent my previous years in Germany and the United States. My experience with the UK system is thus limited, but my experience elsewhere gives me a basis of comparison, and my view as a "newcomer" may be of interest in your deliberations. In the following I address three main points that are of concern to me:

1. the role of CERN and of the UK's participation in it;
2. the importance of a complementary programme, especially in my own field of Particle Astrophysics; and
3. the efficiency of the UK funding mechanisms.

The past few years have seen the LEP experiments at CERN reach an amazing level of precision. This has allowed us to apply very stringent tests to the "Standard Model", which is our present best understanding of the physics of elementary particles. The model has passed these tests with flying colours, giving us strong assurance that we are on the right track. However this same model tells us that it cannot be complete, and that a view into a new regime should be possible at CERN's powerful new accelerator LHC. Experimentation at the LHC will be very difficult, but our success at LEP and the professionalism achieved there and elsewhere gives us assurance that we can meet the technical challenges. UK physicists, along with the rest of the international particle physics community, have decided that the LHC is the highest priority next step for the field, and it is essential that UK physicists have access to this resource so they can continue to do first-rate work. Any decision to the contrary would be a shocking blow to both UK and international physics.

The LHC brings with it the political challenge of increased world-wide collaboration, with a significant financial contribution being needed from CERN non-member states. Such collaboration is highly desirable to allow maximum efficiency in the use of the resources of the international particle physics community, and should be supported for the LHC and also in the planning of future projects such as a linear collider.

Large international projects like the LHC require long-term commitments from the governments involved. A stable balance needs to be found between the funding needed to support CERN directly and that needed on the domestic side for UK physicists to make optimal use of CERN and to pursue other high-priority projects. The CERN subscription inevitably fluctuates with the exchange rate between the Swiss Frank and the English Pound. It is unrealistic to expect the domestic program, which has no influence over the exchange rate, to absorb the consequent extra costs.

Although I have emphasized above the importance of the LHC programme, I feel strongly that it should be complemented on a smaller scale by other first-rate projects. Besides the LHC and the top-down management and planning which it requires, there must be room for a healthy variety of outlets for the creative impulse. We can and should afford to take more risk on smaller projects where this is required to address high-priority questions. A prime example is the search for the missing mass of our Universe. We know that a large fraction of the mass is missing, but we don't know what it is. Thus we cannot design a single experiment with a guarantee of providing the answer. The international community needs to pursue various experimental and theoretical lines, and the UK should make first-rate contributions to this effort.

The new field of particle astrophysics involves various topics of burning interest: besides the nature of the missing mass of our Universe mentioned above, there are also questions such as the acceleration mechanism which produces cosmic rays, and the cause of the deficit in the observed solar neutrino rate. Although PPARC funds both particle physics and astronomy, it is done through separate committees, so that the interdisciplinary field of particle astrophysics still doesn't have a clear place in the structure. Establishing a third committee specifically for particle astrophysics may be a more efficient solution than the present practice of asking groups to apply to both the particle physics committee and the astronomy committee.

Clear structures are needed to allow physicists to work efficiently and set their priorities according to scientific goals, not bureaucratic considerations. There seems to be a recent tendency to split the available funding among ever-more sources: PPARC and its various special programs (PPIPS, ROPA, Fellowships, CASE) the various EU programs, and Royal Society and college research fellowships. In these times of reduced funding we find that we must apply for all of these things, at a large cost in increased paperwork and committee meetings and in loss of flexibility.

The UK participation earns a high level of respect in the international community, due to the high quality and hard work of the UK physicists. This staff is a valuable resource and should be treated properly. A stable and efficient funding base is needed to allow realistic planning of activities, and to continue to attract first-rate people.

Memorandum submitted by Professor J B Dainton, University of Liverpool (10.12.95)

1. PREAMBLE AND INTRODUCTION

1.1 I am presently funded as a Senior Fellow of PPARC, following my election to such a position by the Science and Engineering Research Council (SERC) in 1992. This enables me to spend my time working on research in High Energy Physics, uncluttered by the ever increasing demands of administration and teaching which a university professor faces these days. This has brought home to me that, before even the consideration of the merits or otherwise of PPARC, the ever mounting demands on university academics are reaching levels that make it extremely difficult for them to maintain an effective involvement in their research programmes. The opportunities provided by the fellowship schemes run by research councils and similar bodies for academics at all levels of experience and responsibility are essential if the UK scientific community is to maintain, and in many cases restore, its level of achievement and its reputation, that is if this community is to exploit fully the investment of the nation in a worthwhile scientific base.

1.2 As is clear from the above, my scientific research is in High Energy Physics, or Particle Physics, and not in Astronomy, Space Science, Cosmology, or the other disciplines included in the "A" of PPARC. My experience of these latter subject areas is thus limited, and only recently have I become more aware of the scientific community or communities associated with any or all of these activities.

1.3 I believe that the funding marriage of the two fundamental disciplines of Particle Physics and Astronomy into one agency is a sensible way forward. I hope very much that, by focussing both activities into the only Research Council without the words "wealth creation" (whatever they mean) in its mission, they do not become the easy target of political expediency when budgetary pressure overwhelm.

2. THE VALUE TO THE NATION OF PARTICLE PHYSICS RESEARCH

2.1 High Energy Physics is the sibling of the founding years of the atomic age, the golden years in which the structure of the atom was first elucidated in the early part of this century. The economic benefits of these discoveries are indisputable and ubiquitous. The ultimate reason for the birth of the atomic age in human history was human curiosity. The ultimate reason for the subsequent developments which have given rise to these benefits was the continuing investment by the people of Britain in fundamental, curiosity led, research carried out by the following generations of scientists, who in turn were themselves driven by their own interest and inquisitiveness. All other influences were of only marginal significance. This is as it should be, for all great scientific developments have, without exception, been attributable to such origins. It is therefore appropriate to assess the existence of PPARC, and for that matter other research funding agencies, with this fact in mind. It was therefore encouraging to me to see recognition of this principle of fundamental, curiosity led, research in the words of the PPARC charter when this organisation came into being.

2.2 Nevertheless the nation funds by far the major part of High Energy Physics and therefore has to be able to assess somewhow that there is a continuing return on its investment. The government of the day must rightly expect that the funds it allocates to science are being used for the greatest benefit of all, The latter is achieved and measured in most areas of science which are funded predominantly through the Higher Education Funding Councils and the Research Councils by the yardstick of excellence. Excellence is measured in many different ways which depend on more detailed aspects of different sciences. In High Energy Physics, where large (in UK science budget terms) investment is required at international accelerator laboratories (CERN in Geneva, DESY in Hamburg, SLAC in Stanford) and where the work is collaborative, a major part of this yardstick is the leadership of this collaborative effort by UK physicists from British universities and research laboratories at all levels. Despite the ever increasing pressures on funding and resources, British physicists are to be found in central positions of leadership in a disproportionately large number of activities. The excellence is there to be seen.

2.3 All assessment of the value of High Energy Physics to the nation follows from the application of the yardstick of excellence as outlined above. The leadership of these international enterprises by UK scientists provides access to additional high quality resources, creates opportunities for the development of more young UK scientists, and enhances the strengths and reputation of British universities and research institutions on a world stage. All these activities lead inevitably to immense and unquantifiable "invisible earnings" for "UK plc" of a short, intermediate and long term nature.

2.4 I list some examples of these benefits. The advanced technological demands of these fundamental scientific activities create unparalleled opportunities for industry. Presence of British scientific leadership on the world stage enhances, and in my experience sometimes ensures, that British industry is not forgotten when projects are open for tender. Opportunities for younger British scientists are increased by the influence of senior UK scientists in leading positions. More British scientists move as a consequence into more overseas positions of influence, usually for a fixed term to return to the UK with much (overseas funded) added value, and the benefits continue to multiply. The reverse also of course happens. Younger students from contacts made as a result of this UK influence are attracted to UK universities. They work in our home laboratories, pay fees, gain academic qualifications such as MSc and PhD, and return overseas aware of, and in my experience also very supportive of, the capabilities of UK industry and the opportunities for others to follow themselves. British students, both undergraduate and postgraduate, are attracted to physical science when they see these things in our home laboratories. Whole interlocking webs based on scientific collaboration at the highest level and of the highest quality create immense and unquantifiable benefit for the UK in many different ways. Moreover this benefit can last for working lifetimes.

2.5 I know the above to be true from my own experience with a research group in a UK university. I meet old students all round the world. I meet colleagues who are now research directors in the USA and in Europe. Some of my former students and "postdocs" have moved into industry both in Britain and in countries all over the world imbued with this internationalism and thereby aware of the opportunities for Britain in a world stage. I see their British influence at work in our favour. Many of my PhD students graduate and then take up post-doctoral positions in overseas laboratories. We have students and young post-doctoral scientists from overseas working in my department. I see the budgets, for I am responsible for a large part of their management, which fund the work in our laboratory, and am thus well aware in qualitative terms of the immense returns from the investment of UK funding agencies' resources in our department.

2.6 When viewed in the above terms, the yardstick of excellence can be seen to ensure that there is immense return on national investment in fundamental science, and in particular the High Energy Physics which is supported by PPARC. I believe strongly, like many others, that substantial such investment in fundamental science is, if not the only, then one of the few characteristics of a modern competitive first world nation. PPARC is now the means by which the nation ensures this investment in the areas of Astronomy and High Energy Physics. The existence of PPARC, or of an equivalent organisation or part of an organisation invested with a similar responsibility, cannot therefore be brought into question without also including the international competitiveness and calibre of Britain.

3. UK Particle Physics Funding and PPARC

3.1 Since the late 1970s, that is for the years during the administration of similar responsibilities by SERC, UK funding for High Energy Physics has declined substantially in real terms. This has been despite a slight increase in the national science vote. Less money has found its way towards funding the activities of UK high energy physicist. It has happened during an unprecedentedly successful decade and a half on the international stage, and the consequences in terms of missed opportunities are there to be seen.

3.2 Since the end of the 1970s, funding pressures have been such that UK physicists have had to withdraw from a number of activities. First and foremost the UK community moved all its activities to accelerator facilities overseas. This was in the main scientifically sensible in a contracting funding situation. It has led to the undesirable situation that there are very few young British accelerator physicists. This unfortunate fact has very broad impact on British competitiveness as accelerator technology now plays an important role both commercially and in applied scientific research, such as in medical science, biology, engineering and materials science.

3.3 In terms of very important areas in High Energy Physics, neutrino physics potentially holds a clue to the origin of mass in the universe–until 1980 the UK played a leading role in these experiments and now has little or no involvement whatsoever at a time when discoveries of "neutrino oscillations" may be imminent. The program of high energy muon physics at CERN was instigated and led by the UK. Funding restrictions however had meant that UK activity ceased in the mid 1980s so there has been no involvement in the development of the measurements concerned with the spin dependent structure of the proton and with the "EMC effect" of the changes to proton structure when embedded in atomic nuclei. Most notably, following the end of the proton-antiproton experimental program at CERN, UK physicists have not been involved in any such activities at higher energies at Fermilab in the USA at the Tevatron collider, and thus were not part of the recent discovery of the top quark. These opportunities were missed for one reason only—in the severely declining funding situation the UK High Energy Physics community had regrettably and unavoidably to make choices. It did so collectively and in a disciplined way, producing a long term programme which has been available for all to read since 1992[1]. With adequate funding these discoveries would have been made by British physicists alongside colleagues from the USA, France, Germany, Italy. Japan, Canada, the Benelux countries, the former Soviet Union and other nations.

3.4 The reasons for the decline in funding are broadly twofold. First, given the annual national science vote through the 1980s, the scientific community in the UK has through its committee structure (the CSP followed by the ABRC and the old Research Councils) opted to put less of its cash limited resources into Particle Physics. A major and conscious step in this direction occurred in the early 1980s when the "Kendrew Review" of the subject came to the conclusion that the subject was excellent, essentially using the criterion which I outline above, and then recommended a 15 per cent reduction in funding. Subsequently the SERC found itself implementing a 25 per cent reduction over about five years. Second, that funding which has gone into the subject has always included the subscription to "our" European laboratory CERN in Geneva. Though the UK contribution has changed over these years through renegotiation, the continuing rise of the Swiss Franc has meant that an ever greater proportion of declining resources has gone as CERN subscription. The result is inevitably a rapidly declining resource base for use by UK funding physicists, most of whom of course have to make good use of CERN with these rapidly diminishing funds. The effect has been to erode substantially the excellence, as I have defined it above, of British High Energy Physics. The return to "UK plc" is substantially less than in the late 1970s though the cost of that part of the investment which is placed in CERN has increased in real terms.

3.5 This declining funding scenario has many further implications. It removes flexibility in planning. No-one knows where the next big discovery will occur. When resources are scarce and projects are large the scientific "gamble" of putting resources where the next discovery may be and not putting them where it may not be is maximised because in no way is it sensible to spread resources too thinly. The foreseeable future of High Energy Physics is built round, and not just on, the LHC at CERN in which proton collisions will be observed at collossal energies. The case for this project is irresistable scientifically—answer to the most fundamental questions concerning the universe from its macroscopic nature to the fundamental constitutents at the smallest scale may emerge from new, important and exciting discoveries. However who knows if it will answer the right questions ? If one did, it would start to bring into question the reasons for trying—for it is that uncertainty that makes all fundamental rearch worthwhile. Present funding levels in the UK mean that the exploitation of LHC is itself anyway in jeopardy and certainly very little else will be possible if the funding does not revert to levels equivalent to at least a decade ago in real terms. This is an extremely unhealthy situation for any science. It is exacerbated by the inevitable reduction in opportunties for younger scientists. Not only are there fewer jobs and less money to support them in their activities, but there are reduced opportunities for them to follow their own scientific judgement and make the discoveries of the future. In short the declining funding scenario year by year kills more and more of the essential seed-corn on which progress depends. Thereby it is killing off the value of the returns, outlined above, on the investment by the nation in such fundamental research both now and into the future.

3.6 The inexorably decline in annual funding has recently reached levels which, following years of painful and unfortunate adjustment, I now find from direct experience to be both illogical, extremely alarming and unprecedented. The illogicality arises from the fact that the major part of our present experiments which are producing data are concerned with high energy electron-proton interactions at the LEP collider at CERN, Geneva and high energy electron-proton interactions at the HERA collider at DESY, Hamburg. Both these enterprises involved years of investment in constructing the detectors in the 1980s. Data of great significance are now being taken. Yet the funding levels are now such that the involvement of physicists with these activities is hindered to a degree which is almost fatal—in other words the return to the nation of its investment a decade ago is being curtailed prematurely. The alarm arises because of its immediate effect on young physcists, many of whom have fought their way into the front line leading these activities on a world stage and who are now unable to maintain close enough contact with those who seek their direction from institute around the world. I have such young people working with me. I am not alone in the UK community in saying that the funds made available to me are insufficient to permit then to continue leading the world in their chosen areas of expertise. They have to withdraw from regular contact with those whom they lead, and work more only in the UK—there therefore is a visible loss of excellence. If I do arithmetic on it in terms of the number of scientists who are restricted in their contact with colleagues at their experiments I can quantify it as a reduction of about 50 per cent in the last three years. By my criteria above, this is a reduction on excellence of similar proportion and thus a reduction in the nation's return on its investment over at least the last decaade. This is tragic for them, for the nation and for science, and is completely illogical given the magnitude of the funding shortfall as a proportion of total government expenditure. Since becoming a professional physicist in 1973, I have never experienced such potentially disastrous cuts. It is quite unprecedented in my experience. I do not know whether the onset of this latest reduction has anything to do with the birth of PPARC and the other new Research Councils.

4. Funding Priority in PPARC

4.1 Therefore the top priority of PPARC must be to restore funding to a level where the UK High Energy Physics community can work alongside, and on an equal basis as, their counterparts from abroad. To do this it must be provided by government with adequate funds.

4.2 Recently PPARC has put before government a funding scenario which would:

- ensure adequate funding for UK particle physicists to prepare detectors for the LHC experiments;
- continue a healthy programme of physics at the LEP (electron-positron) and HERA (electron-proton) colliders where there is much of vital importance to be done and in which a major investment was made in the 1980s preparing experiments for the 1990s and beyond;
- prepare for and exploit fully opportunities which arise in areas such as the SLAC B-factory (electron-positron collisions with asymmetric beam energies) to study heavy quark physics;
- invest in on-going opportunities to do smaller experiments either at accelerator laboratories or using cosmic rays.

I believe that the request amounts to a responsible assessment of what will ensure that the investment by the nation in British High Energy Physics will give maximal return in the ways outlined above. In terms of the UK GDP, it represents a tiny sum of money. In terms of the increase in the PPARC budget it requires a significant increase in funding. I am not an economist, but the sums can be put into some proportion in the following way. To remedy the funding shortfalls in PPARC which are now causing so many problems for High Energy Physics requires additional investment at a level which is a small fraction of the uncertainty in the annual Treasury forecast of government PSBR, and not of the forecast itself. In the language of science it is truly "in the noise" of the nations's annual expenditure. This must also be the case for the Astronomy brief in PPARC where I know that there are similar problems.

5. Specific Points Raised in the Press Release 19 October 1995

5.1 *How important is it that the UK continues to participate in "big science" projects such as the Large Hadron Collider?*

The LHC is the foundation stone of the future of High Energy Physics, Without it, in the next 20 years experiments which probe the nature of physics at distance and time scales appropriate for answers to fundamental questions such as "what is the origin of mass?" and "why did the universe develop in the way that we find it now?" cannot be attempted. The distance and time scales of the interactions at the LHC amount to tiny fractions of those of the fundamental constituents of matter as we know them to be now, namely quarks and electrons. The experiments inevitably address the nature and origin of quarks and electrons and so address how they make the universe be the way it is now. These questions and many many others have been asked over and over again and in seeking answers humanity has developed to its present state of advancement both materially and spiritually. I regard it as essential that people in the UK continue to be part of any aspect of human activity concerned with such great questions.

Without the LHC, High Energy Physics is unable to go where the success of its research since its beginnings now lead. Worldwide, the subject will die without the LHC.

For more specific justification for High Energy Physics, and thus the LHC as the basis of the subject in the UK, see section 2 above.

5.2 *Are UK scientists able fully to exploit this type of collaborative facility?*

Without a signficant increase in UK funding, there are at best severe difficulties and at worst impossible obstacles to overcome, some of which I consider to have reached crisis levels in the last two or three years (section 3 above). These difficulties arise from serious mismatch of UK domestic resources and overseas subscriptions. It is clear that the huge proportion, and not total sum, of PPARC's budget which is earmarked for international subscription is presently having a disproportionately bad influence on its scientific programmes (section 3 above). The nation can easily afford these subscriptions. In considering the size of the science vote annually, the government must take more into account the effective use of these subscriptions and recognise that additional funds should be made available for their efficient exploitation (section 4 above). The additional funding necessary is not at all large in terms of government spending.

5.3 *How should international projects best be managed and funded?*

It is clear to me after many years both of watching activities and of working at CERN that there is throughout its activities very little mismanagement and misuse of resources. This is quite simply because such a place is driven by scientists of the highest calibre who ultimately do what they do because of interest and curiosity and not out of personal financial gain. However, given the magnitude of the task of managing an organisation of the size of CERN, the problems arise in the degree to which governments of member states maintain their commitments to the collaborative effort as they try to keep to the international agreement behind the existence of the laboratory. I see no reason to change the present structures built round a council of member states and associated committees until such time as there is obviously some supra-national authority which encompasses laboratories such as CERN as a result of greater political and economic union, such as for example a more democratically accountable EU (with Switzerland as a member!).

5.4 *How appropriate is PPARCs structure for its research portfolio?*

It is early days yet. However, it is interesting to note the real impact in PPARC of the moves towards more decision making and direction at the executive level, with the consequent reduction in influence of peer review which has been the thrust of the reorganisation of all the new Research Councils, The executive has maintained the essential committee structures of SERC in Particle Physics and the way in which they work, presumably to ensure a sensible flow of advice and information to help them make decisions. It would seem that though imperfect in many ways, the old peer review system is again shown to be not as imperfect as attempts to replace it! One hopes that, though not now legally bound to peer review decisions, the executive will remain mindful wherever possible of the wishes expressed through these committees of the community, the funds for whose work they administer and now allocate.

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Memorandum submitted by the IPMS (13.12.95)

EXECUTIVE SUMMARY

1. The Institution of Professionals, Managers and Specialists (IPMS) is the trade union which represents scientific and technical staff in the PPARC (Paras 1-2).

2. The IPMS believes the PPARC is properly constituted to deliver its mission (Paras 3-11).

3. The PPARC has had funding difficulties arising both from its international subscription commitments and its reduced science vote funding since its separation from the old Science and Engineering Research Council (SERC) (Paras 12-13).

4. The Executive's response in reducing staff and for selling its building assets is likely to lead to a reduction in projects and excellence which threatens the return from the long term scientific investment (Paras 14-21).

5. The IPMS believes only continuity and long term funding of the PPARC scientific teams will allow the continuation of excellent scientific research and development (Paras 22-25).

PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL

IPMS SUBMISSION TO THE SCIENCE AND TECHNOLOGY COMMITTEE INQUIRY

INTRODUCTION

1. The Institution of Professionals, Managers and Specialists (IPMS) is a trade union which represents 80,000 scientific, technical and specialist staff in the Civil Service and related bodies and major companies. In particular, IPMS represents scientists, engineers and technicians in the PPARC.

2. The IPMS submitted evidence prior to the Government's Science White Paper published in May 1993 (Realising our Potential. A Strategy for Science, Engineering and Technology) and then again to Sir David Phillips' Research Council Boundary Study. The White Paper proposed the creation of the PPARC and the Boundary Study confirmed the areas of research the council would undertake. In essence, the IPMS supported the division of responsibilities but were concerned that the funding reallocations proposed may not have been adequate to support the functions which fell to the new Research Councils.

The Contribution of PPARC

3. At its creation, the PPARC was given the following mission:

> "To promote and support high quality basic research and related postgraduate training in astronomy, planetary science, and particle physics, which takes account of the potential for contributing to the United Kingdom's industrial competitiveness and quality of life, but whose main objective is the improved understanding of the concepts and principles underlying physical phenomena and their consequences."

This mission has been subsequently confirmed via the Forward Look review process.

4. The IPMS believes that the structures and expertise of the PPARC has allowed it to properly discharge this mission. Decisions on what research is to be done and how it will be delivered are made by peer group review amongst the international and academic communities.

Basic Science

5. Excellence in basic science research is achieved by making world class instrumentation available to a community of university based researchers. The most fundamental discoveries in astronomy have been made using the most powerful (and expensive) telescopes combined with the most sensitive cameras and spectrometers. The PPARC Royal Observatories have a long and distinguished record of supporting world class astronomy. The academic community which is supported by the facilities provided by the Royal Observatories has great faith in the services provided and in the technical and scientific staff.

6. In the nineteen seventies and eighties, the UK achieved a world leading position in the exciting and technically challenging new field of infrared astronomy. This was done by building the UK Infrared Telescope (UKIRT) in Hawaii and equipping it with instrumentation built primarily by a national centre of excellence for infrared technology at the Royal Observatory Edinburgh (ROE). This coherent strategy allowed the exploitation of the discoveries that were being made at that time by the pioneering space based infrared telescope, IRAS. This has helped British astronomers to repeatedly steal a march on their colleagues abroad, and allowed UKIRT to make an impact on practically every aspect of modern astronomy from comets to cosmology.

7. The principal task of the Royal Greenwich Observatory (RGO) during the past decade has been to build, commission and operate major optical astronomical facilities on the Spanish island of La Palma. The work has been done in collaboration with international partners, primarily Spanish, Dutch, Irish and Danish.

8. The common-user instrumentation for the Isaac Newton Group of telescopes (ING) on La Palma is primarily developed, installed and operated by members of staff of the RGO. This has proven to be a highly productive relationship. Scientific papers resulting from observations made using these telescopes and instruments are among the most cited papers in optical astronomy.

Future Research

9. Last month, some fifteen years after IRAS, another poineering space based telescope, the Infrared Space Observatory (ISO) was launched by the European Space Agency. Once again, the UK has invested a large fraction of its science budget in an infrared satellite that is bound to make revolutionary discoveries, but, critically, it has left UKIRT without any long wavelength infrared instruments capable of following them up. Instead, we are forced to offer valuable observing time on UKIRT to German and American groups in exchange for the use of their cameras. Further cuts, be they to telescope operations or to instrumentation budgets, will lead to more of these deals becoming necessary, with UK astronomers having less direct access to UK telescopes.

10. The next big investment of money for ground-based British astronomy is in the infrared optimised eight metre Gemini telescope in Hawaii, a project dominated by the US and with the UK paying for a quarter share and with RGO and ROE playing major roles in the development of instruments, systems and software. This money can only be regarded as having been wisely spent if the next generation of British astronomers are trained to make full use of Gemini and the results of ISO by having continued access to the best telescopes available now.

Post-graduate Training

The Observatories also have a long history of training and developing the highest quality scientists and engineers required to develop and build the facilities required for today's competitive high technology astronomy. As part of PPARC it is possible for the Observatories to invest long term in the future staffing requirements of the programme. This training is highly respected by industry with whom there is a constant exchange of personnel.

The Funding Problem

12. However, the fundamental nature of the PPARC's work is long term. The investment has been made but continued funding is essential to maintain the structures and expertise to exploit the future benefits which accrue. Sadly, this seems not to be happening.

13. Sir David Phillips wrote in his Research Council Boundary Study:

> "I note that the programme of PPARC relies very heavily on international collaborations, with more than half its financial resources being devoted to the payment of subscriptions which secure access to facilities, but which do not provide for their exploitation. In addition, much of the domestic programme comprises long term commitments (for example, to space missions), with lumpy expenditure profiles that may cause handling difficulties within a budget that is significantly smaller than that of SERC. The new Directot General may wish to consider with the PPARC's Chief Executive possible measures to help alleviate such planning difficulties."

Unfortunately, his concern has proved to be justified both with regard to international commitments and the allocation of science vote funds.

The PPARC Executives Response

14. Since its creation, the PPARC has been subject to a series of internal reviews, particularly the Optical infrared and Millimetre Wave Astronomy Strategic Review chaired by Professor Jim Hough of the University of Hertfordshire.

15. Whilst reconfirming the strategic thrust of the PPARC's research, it is clear that the main issue has been current and future funding difficulties.

16. Given that most of the Council's funding is committed to international subscriptions on long term projects, the Executive has concentrated on aspects of its budget it can divert: buildings and staff. In essence, the strategy has been to investigate the possiblity of the confirmed UK Astronomical Technology Centre, which could free up property for sale, and to shed staff, either by transfer to another body or through redundancy.

17. The IPMS believes that either strategy can only be carried through by a reduction in the research and at great risk to the long term projects under way. It is our view that the benefits of past investment can only be gained by continuity and continued funding of the research teams currently employed by the Council.

18. Further concern has now been raised with the publication of the Government's response to the Multi-Departmental Study of Public Sector Research Establishments which announced a Prior Options Review of the PPARC. That Review Panel, chaired by Professor Ian Halliday of the University of Wales, Swansea College, is due to report to Ministers early in 1996.

19. Given the Council's difficulties and attitudes, there is no doubt that the Review Panel will address the current management structures.

20. Whilst we accept the need to review current management chains and to give greater autonomy to the observatories and especially the island sites, the IPMS does not see that the current research can be done anywhere but in the direct control of the PPARC.

21. At risk from any move to a private sector or University environment are the currently perceived advantages of the PPARC. These are:

- prioritisation of research by peer review
- scientific neutrality
- long term planning
- financial and scientific accountability
- trusted service provision
- responsiveness to changes in priorities
- atttactive career environment
- proven training provision, both internally and externally.

Conclusion

22. The IPMS believes that the PPARC has proven capable of successful delivery of its scientific mission.

23. There are obvious funding difficulties which threaten any return from the committed long term investment.

24. Any response to the funding difficulties which threaten the continuity of the scientific teams currently within the PPARC can only be to the detriment of scentific projects and excellence.

25. The IPMS believes that these issues need to be addressed by the Select Committee's Inquiry and would welcome the opportunity to give further evidence, oral or written, if this would assist the Committee's work.

Memorandum submitted by Royal Astronomical Society (15.12.95)

The Scientific Remit of PPARC

The Particle Physics and Astronomy Research Council is the major source of funding for fundamental research into astronomy and geophysics in the UK. These sciences cover our understanding of the whole universe, its origin and future development, the nature of the naturally occurring bodies in the cosmos, the physical mechanisms by which they are formed, interact and radiate, and the detailed features of the Earth and Mankind's only habitat. These are some of the most profound areas of scientific study and this makes them interesting and attractive to the the brightest students and the general public, including young people deciding to enter science as a career.

The fundamental nature of the problems addressed in astronomy and geophysics require for their solution a high degree of theoretical innovation, sophisticated instrumentation of novel design and challenging performance, together with analytical and data processing techniques that stretch the limits of both software and the available processors. This kind of activity is funded for its intrinsic interest and importance but the potential exists for the benefits of the technical advances to be shared by completely different fields of endeavour, even those with commercial or industrial application.

Astronomy in particular is of immense importance in attracting school children to science. Many go on to further studies of a variety of physical sciences, and to subsequent employment in science based industry. Astronomy thus stimulates and supports the science base in addition to providing highly trained graduates or postdoctoral staff, many of whom also proceed into science based industry.

The Royal Astronomical Society strongly endorses the policy of placing the management of particle physics and astronomy within the same research council. The subjects have many points of scientific contact, cosmology is one example, and face similar organisational issues to do with international subscriptions, long time scales for major projects and a high technological potential.

The Scale of PPARC Science

The sophistication required in current investigations in fundamental science such as particle physics and astronomy is clearly demonstrated in the scale of projects such as the Large Hadron Collider, the Gemini 8 metre telescopes and space missions such as ISO and SOHO. In the case of astronomy though, much of the scientific *exploitation*, can be and is carried out by rather small teams, sometimes one academic plus some research assistants and students. So, while the provision of the experimental apparatus or observing facility is a large endeavour, these capital projects support many separate investigations over several years, or even decades, and there are large user communities for these facilities. The definition of this activity as "Big Science" is then neither accurate nor helpful.

In astronomy and some areas of geophysics the scientific issues of current concern frequently require access to large and expensive facilities. This requirement derives from the need for large telescopes to study objects at great distances or to obtain high spatial and spectral resolution. Some objects in the universe emit radiation at wavelengths which are absorbed in the Earth's atmosphere and to understand the physical mechanisms at work it is necessary to use instruments mounted on space platforms. In geophysics there is the need to construct large ground based atmospheric radars for the study of the ionosphere and the magnetosphere. These large facilities needed for modern, world class, astronomical and geophysical research are best supported by means of international collaboration to share the cost and broaden their use. It is therefore natural that PPARC is heavily involved in international collaborations at the individual project level, in addition to its membership of organisations such as CERN and ESA.

Many astrophysical sources emit radiation from material with a wide range of temperatures, so observations have to be carried out over a broad wavelength range in order to understand the physical processes occurring. Thus it does not make scientific sense for the UK to concentrate resources solely on one wavelength region and abandon the others. The projects and instruments selected, under very competitive conditions, are those that maximise the opportunity for UK scientists to remain at the forefront of discovery and exploitation. The apparent diversity of the programme arises from the nature of the science.

The Role of the Observatories

The fact that even small individual academic groups can achieve world prominence in their chosen specialisation is due in no small measure to the availability of well run facilities for making observations. The support provided by the Observatories is therefore vital if the health and efficiency of UK astronomy is to be maintained. The restructuring of the Observatories, on which PPARC is currently engaged, must take into account the provision of a mechanism for the future upgrading of instruments and telescopes. There are many means by which this can be achieved, but the functional support for observers must be maintained.

THE PPARC SPACE SCIENCE PROGRAMME

The UK scientific community derives enormous benefit from the international programmes organised via PPARC. Although it is only a minor member of ESA the UK is widely regarded as being extremely effective in gaining high scientific output from its membership of ESA. Recent EC reports show that for our 14 per cent subscription we generate 28 per cent of the published scientific results in space science and Earth observation. The quality of our instrumental development is highly praised and UK scientists have been very successful against international competition in gaining places for their instruments in European space projects.

The scientific quality of the ESA space science programme is now rated as being second to none in the world. This is an extraordinary achievement in which the UK has played a significant part. However, the provision of the membership subscription alone does not create a high quality scientific programme in space science since the scientific instruments which are at the cutting edge of new discoveries are funded nationally, by PPARC in the UK. Unless PPARC plans include a line in its budget which provides for space instrument funding at a level which is in some way related to the subscription it pays for membership of ESA, the success of the UK space community will atrophy. Recent events (the inability to fund UK led instruments for the Integral mission), have shown the disastrous effects of neglecting this simple planning procedure. ESA has a clear space science programme and despite uncertainties in the future funding for science as a whole, and PPARC in particular, it should be possible to make a long-term plan for the UK involvement in this programme. However, because of the long-term nature of the work it is crucial for PPARC to have stable funding. PPARC should be encouraged to demonstrate its full support for ESA by reinstating such a planning mechanism for its space science programme. The limited sums of money available for this area of science must be carefully deployed if the UK is to exploit its membership of ESA to the full.

The nature of decision taking in a multi-national organisation such as ESA means that the UK can find that a subject area of particular national interest is not supported for a period of some years by means of ESA projects. It has been frequently the case that bi-lateral opportunities with the USA, Japan, or Russia are offered to UK scientists as a means of filling these gaps and maintaining progress in certain fields of high priority. These bi-lateral programmes are a crucial admixture to the main PPARC commitment to ESA and often allow the development of instrumentation skills which place the UK in an advantageous position when a suitable ESA mission is planned.

Although the priorities for scientific involvement can be established, there are major uncertainties in the funds available, as a result of currency fluctuations and volume changes in the subscriptions to international bodies. In any year the effects of changes in the CERN or ESA subscriptions can exceed the size of the national budget required to exploit the membership of the international organisation itself. This is a severe limitation on the ability to execute the plans effectively. The combination of a national subscription to obtain membership of an organisation such as ESA or CERN and a PPARC budget line to pay for the scientific contribution to each separate project is an effective method of participation in this kind of science only if the funding for the national project contribution is of sufficient size and stability to support the long term projects undertaken in these fields. It is simply not possible to descope the funding for, say, a space project due to a budget crisis when all the international partners are depending upon UK fulfilling its technical commitments. Further thought should be given to providing PPARC with mechanisms regarding the payment of international subscriptions which would permit more effective long term planning of the programme.

UK research groups in universities have has a long and successful experience of managing international projects. They understand the technical and policy issues very well. Indeed, the advice of UK scientists is often sought by international organisations on these matters. Given the very competitive costs of UK scientific instrument teams, it might be concluded that current practices are close to optimum.

THE STRUCTURE OF PPARC'S DECISION MAKING PROCESS

A major feature of the change from SERC to PPARC has been the extra power taken by the PPARC Executive in making decisions on which projects to fund at what level. In SERC these decisions were strongly influenced by the endorsement of subject area committees. There is a growing concern that the advisory bodies, especially the Astonomy Committee, are only being used so far in a rather infrequent and limited way, with quite major decisions being taken by the executive, sometimes are rather low levels. While respecting the desire of the OST to limit the commitments extra duties and to reduce the bureaucracy of large committees, it is felt that the experience and scientific authority of the majority, but by no means all, PPARC staff is not sufficient for them to make decisions which the astronomical community will accept. This concern applies both to decisions as to which projects should be funded, which might be reduced in scale or even cancelled and how projects should be managed. The astronomical community has a wealth of experience to offer PPARC and a willingness to play an active role in making the best of limited funds. PPARC should be encouraged to move some of the decisions of importance back to the community which has in the past shown itself capable of self-regulation and positive action in support of well defined goals.

The RAS Council regrets the decision by PPARC not to include on PPARC Council an RAS assessor. There are many important areas of interface between PPARC and the RAS, which is the professional body representing half of PPARC's community. Issues of Public Understanding of Science, input to the secondary education system and demographic trends in the science groups active in astronomy are all of joint interest to PPARC and the RAS, and there have been good contacts in some of these areas. However, it has become more difficult to maintain contact between PPARC and the wider community. The RAS Council suggests that the decision not to invite an assessor from the RAS should be reviewed.

At the formation of PPARC it was decided not to have the chairpersons of the Particle Physics Committee and the Astronomy Committee as members of PPARC Council. This is much regretted by the Council of the RAS. It has created a gulf between the astonomical community which PPARC aspires to serve and the PPARC Council where important issues of policy are decided. The combination of this lack of contact between PPARC Council and the Astronomy Committee on one hand, and the lack of programme responsibilty implicit in the terms of reference of the Astronomy Committee on the other, leaves that body with little influence, apparently by design. As a result the community feels an increasing lack of ownership of the programme that it has done so much to create and operate.

SUCCESSES OF PPARC

The White Paper "Realising our Potential" required each of the new research councils to carry out a duty of infroming the public about their work. The RAS Council wishes to draw attention to the excellent publicity programmes mounted by PPARC surrounding the launches of SOHO and ISO. The provision of sufficient resources to prepare professional quality material has been especially important in gaining access to appropriate media channels. The possibilty of university grant holders being awarded funds for public awareness schemes is very much welcomed by the RAS Council.

CONCLUSIONS

The Council of the RAS recognises the exciting portfolio contained within PPARC's remit and is pleased that the policy issues in particle physics and astronomy are being dealt with coherently. with some attention to the interface between PPARC and its astronomical community this research council may become a model for the provision of government funding for a fundamental science. There is excellent science to be done; just how much can be achieved depends critically on a sufficient level of stable funding.

Letter to the Clerk of the Committee from Professor David Southwood, Imperial College of Science, Technology and Medicine (15.12.95)

I write to the committee from experience of PPARC in three separate capacities. I am a planetary scientist dependent on PPARC for research funding and representation in ESA and other agencies. I am the head of the country's largest university physics department where, in common with other top rank physics departments, a large fraction of our departmental research council funding comes from PPARC. Lastly, I am currently chairman of the ESA Science Programme Committee and so I see PPARC partly through the eyes of European colleagues.

I shall proceed by addressing questions in the Press Notice and by adding allied questions of my own.

HOW IMPORTANT IS IT THAT THE UK PARTICIPATE IN "BIG SCIENCE" PROJECTS?

I start from a view that the discipline of physics is of fundamental importance to the educational, cultural and industrial health of an advanced nation. Physics is one of the great underpinning disciplines of basic science. Astronomy and particle physics are significant parts of physics. They are the parts of physics which have the highest public profile. Here is their strength. Astronomy, in particular, is inspirational. My engineering student son decorates his room with Hubble Space Telescope pictures I give him. But it goes far beyond my family, I have just spent the past few days talking to newspapers, TV and radio about the Galileo spacecraft's arrival at Jupiter; public interest has been palpable and rightly so. Galileo, which will not only tell us a lot about Jupiter but a lot about our own planet and the solar system as a whole, is an extraordinary technical achievement.

PPARC scores highly on educational and cultural relevance. The balance between educational, cultural and industrial health is important. I do not see that a developed nation can afford to select only one or two from the three. One should understand that PPARC science is not detached from industrial concerns. In my area the ESA space science programme is regarded by our industry as an important shop window for their skills and as a way of developing new skills on programmes that inspire their workers. The technology of sensors, devices and information transmission which are critical to all scientific areas (from medicine at the practical end to, say, astronomy at the cultural) are underpinned by basic physics and original physics research.

How appropriate is PPARC's structure for its research portfolio?

I have found it hard to determine how policy is determined and set in PPARC. There is little or no vertical linking from junior panels to senior. I worry too much power devolves to the executive. Like many scientists I think that support of excellence should be the aim and despite its imperfections I have enormous faith in peer review and keeping policy directly connected to the community. Despite these comments, I think that people like the PPARC Chief Executive have done a good job of communicating with the community and that as a result the scientific community does know the problems he faces.

Is a separate Particle Physics and Astronomy Research Council a good idea?

The two science topics both ask fairly fundamental questions about the physical universe; but there are many other branches of science where fundamental questions are asked. What distinguishes the two areas is that they both are tied to large European organisations, namely CERN and ESA, as well as other smaller international cooperative activities (such as the Anglo-Australian telescope or the new Gemini telescopes).

Putting particle physics and astronomy in a single entity is not necessarily a bad idea but one must ask what were the motives. For a long time there has been in a section of the UK science establishment a suspicion of "Big Science". If the intention of placing the particle physicists and astronomers with their large international subscriptions which dwarf the domestic programmes is in some way to isolate and squeeze the big scientists further than they have already been squeezed it is a bad thing. Small percentage changes in subscription can have a horrendous impact on domestic expenditure profiles which then in turn cripple the ability to exploit the large investments made.

Separating out particle physics and astronomy as "pure" sciences somehow ring-fenced from the real world is not a good motive either. Much of "EPSRC" physics is also basic or fundamental and thus must look to research council support for its main funding. Furthermore the boundaries are not distinct. PPARC scientists both require and build advanced sensors, complex data taking and processing and drive high tech development like other physicists and their links to industry need be no more and no less than many scientists working in basic physical science.

In my own area of expertise, space science, the separation of space studies of the universe (in PPARC) from Earth observation (which has gone to NERC) has complicated further a national approach to space activities; many skills and technologies are needed in common by space science and Earth observation. One should not discount the importance of a coherent technical and political approach to something requiring the large level of investment as space. One wants as much as possible to make economies of scale and encourage cross-migration of approaches from different types of space activity. PPARC only covers a small fraction of national space usage. In the last year I gave evidence for a review of all French space activities chaired by M. Francois Fillon, at the time the Minister for Research in the Balladur government. I underwent some questioning on topics of UK space policy ranging across many uses of space from space science through to military issues. I don't think I did too badly in representing national views as well as my own but then I am generally interested in space activities. A PPARC representative would have had difficulty through their limited brief. In this respect the "Surrey seminar" run by BNSC and chaired by Ian Taylor which got industry, scientists, engineers, and commercial space interests together was long overdue and things may be moving in the right direction.

How has PPARC performed on the international front?

I am best able to comment here on ESA rather than CERN. Mr Taylor, the British Minister, showed great political skill in the Toulouse conference in persuading the other 13 ESA member states to decrease the science subscription in the coming years. One should not discount his personal contribution to this coup which was against the stated position of the other member states. I was less impressed by the preparatory work. Mr Taylor was briefed by PPARC that a large cut could be sustained without damage to the programme on the basis of arguments not accepted by any of our partners. I share Mr Taylor's belief that ESA and European industry could be more efficient. One needs to understand that it is not simply in the gift of the ESA executive to deliver it tomorrow. It requires a big political fight to give that executive the environment where they can achieve that end. The fight has only just begun; it is not clear that the UK and its allies will win. One should be under no illusion that the large advances required to save the ESA science programme from harm are anywhere near being achieved. My approach would have been nowhere near as antagonistic as British policy has been in the ESA advisory bodies (including the one I chair) last year. For me, I always recall the Hague conference of ESA in 1988 where I feel a British failure to communicate diplomatically set ESA off on the wrong course. I worry that anti-UK feeling will lead to subversion of its aims in an organisation where we have had enormous past influence.

The PPARC press release following the Toulouse conference was greeted with scepticism, by our partners in the ESA science programme and the PPARC spokesman's view of the meeting as a triumph for science was gently ridiculed by the international science journals, "Nature" (26/10/95) and "Science" (27/10/95). I would urge any committee members to read the articles following the Toulouse conference in those journals and to note the use of inverted commas.

Are UK scientists able to fully exploit ESA or CERN facilities? I

There is no doubt that the British particle physics, ground-based astronomical and space community still has the intellectual capability to exploit ESA, CERN or other international facilities.

Following the recent failure to fund a serious UK involvement in the Integral space mission, it is clear that we are underutilising these facilities. The imminent likelihood of less than full funding of UK instrumentation for the LHC and the limitation of the British role in the new ESA Rosetta cometary rendezvous mission to a level that there can be no principal investigators on the Orbiter spacecraft suggest to me that the situation is still serious. In most people's career opportunities for any particular mission come infrequently. There will be no alternatives to Integral, the LHC or the Rosetta programme for British scientists.

PPARC when formed, found it had inherited an overheated programme. The problems themselves are not surprising. One needs to see PPARC given a clear idea of its long term funding and then for it to develop some long term programme where there remains a solid level of funding for exploiting our international subscription.

Are UK scientists able to fully exploit ESA or CERN facilities? II

One may also ask the question from a European point of view. Individual British scientists remain highly respected and this is the motivation for our colleagues retaining British involvement in programmes. The disruption caused by British parsimony can irritate our partners. For example, the ESA Science programme will likely be reduced by about 15 per cent in the next five years. Several times it has been pointed out to me by European colleagues that British withdrawal from ESA would reduce the Science Programme by only 12 per cent and the Agency's overall programme by six per cent.

Why does the UK find maintaining its GNP-based contribution to programmes like ESA's so difficult?

I would like the answer to this question but do not know it. It is not a new problem for Britain. The requirement of unanimity at ESA Council for determining the Science Programme level of resources was, I understand, imposed in 1964 by a UK delegation to the ESA predecessor, ESRO, concerned about not having a repeat of the 'run-away' costs of CERN. Other nations certainly have problems meeting their commitments; none seem as continually troubled as the British.

Coupled with this is the confrontational approach that I sense comes from the enormous frustration in the UK in organisations like PPARC that the UK has to compromise in an international agency like ESA because it is necessarily a minority partner. Oddly enough, although attitudes change from country to country I think that the level of frustration is much higher in the UK than elsewhere. I have no explanation for what seems almost a cultural issue.

Is ESA the way for the UK to pursue space science?

I see ESA as the only way for the UK to remain in truly world class space science activities. Do we then need space science? I feel we will be a much diminished nation if we did not have it. I would not want to tell our schoolchildren that to explore the solar system or the universe, it was necessary to emigrate. However given our economic limitations, at some point, it may be considered to be in the national interest to withdraw from ESA. We are not there yet. I would say that as long as we have an effective space industry we need to be in ESA; I am sceptical of how our industry would survive without the underpinning ESA programme. The UK space industry has a turnover in 1993–94 of £710 million—for comparison the ESA subscription is about £40 million.

Nevertheless, because we need ESA, it should not mean that we should not try to change ESA. It is clear that ESA needs to change and one wants to see some of the UK's wishes on efficiency effectively introduced. However it is not clear what is the most effective approach. My own prejudice is to be diplomatic but to be clear-sighted over what is needed. We may reduce our contribution to the programme faster in the way we have been going recently but we will also reduce our return by this means; it is not a way to win influence.

I hope that my comments are useful to your committee's deliberations.

Memorandum submitted by the Institute of Physics (15.12.95)

1. INTRODUCTION

The Institute is pleased to have this opportunity to comment on the role and work of the Particle Physics and Astronomy Research Council (PPARC) on matters of relevance to both particle physics and astronomy as well as to other branches of science.

2. THE NEW STRUCTURE

PPARC is modelled to a large extent on the structure developed by the Science and Engineering Research Council (SERC) for the two major areas of science which it supports. The SERC scheme worked well enabling scientific priorities to be established and funding requirements to be clearly defined. Equally, the system for peer review and for obtaining advice on policy issues was sound and transparent as were the arrangements for financial planning and fund management for experiments. For particle physics, there arrangements were managed through the Rutherford Appleton Laboratory and proved to be robust and sufficiently flexible.

Compared with its predecessor, PPARC has a leaner "management". This makes, perhaps, for greater cost-effectiveness but possibly at the expense of less satisfaction to the physics community.

Changes have been made, for example, which affect the relationship between the Particle Physics Committee—which provides input on policy and priorities—and the PPARC Council, and also between the Committee and the peer review bodies. The Committee is now advisory to the PPARC executive but does not formally have a voice on Council. The peer review bodies were previously sub-committees of the Particle Physics Committee but now submit their decisions directly to the PPARC executive for approval. It is too early to say whether such changes will enhance, or detract from, the quality of the decisions made.

The Rutherford Appleton Laboratory, previously a part of the SERC, now falls within the remit of the new and independent Council for the Central Laboratory of the Research Councils (CCLRC). The Laboratory's activities within particle physics draw on a wide base of scientific and technological skills and are a fully integrated part of the overall UK programme in this field. The Laboratory provides technical support for the programme as well as participating in it. University staff have easy access to the Laboratory, its staff, its services and facilities. This role is now defined and funded through a Service Level Agreement between PPARC and the CCLRC. There is no obvious reason why the new arrangement should not work as well as the one which preceded it and the Institute is concerned to ensure that the new arrangement will be effective, particularly with the Large Hadron Collider (LHC) development underway.

3. PRIORITIES

Decisions on priorities within the scientific programme supported by PPARC are taken by the council after consideration of input from peer review and policy making bodies. The Institute is content that PPARC's current priorities are fully appropriate. In particular, the Institute fully supports the continued membership of CERN.

CERN gives UK scientists access to unrivalled facilities for research in particle physics. The UK has played its part in building up the laboratory to its present pre-eminent position.

The current Director General and many of his senior staff, including the leader of the recently approved LHC project are British. UK scientists have always been prominent in the research carried out at CERN. At present, they are in leading positions in the experiments planned for the LHC. PPARC continues, quite rightly, to give high priority to the LHC and to supporting the UK's participation in LHC experiments. Starting early in the next decade, these experiments will be at the forefront of research in particle physics.

PPARC has also recognised that some room must be left in the particle physics programme both to support high quality proposals in areas not covered by the LHC and to enable new ideas and unexpected developments to be followed up. Future funding must be at such a level that PPARC can pursue effectively its programme in both particle physics and astronomy.

4. FUNDING

The funds allocated to PPARC amount to some £185 million per annum, divided between astronomy and particle physics. The funds for particle physics are subdivided into two distinct parts. By far the larger part £67 million, about 70 per cent, is given to PPARC to fund the UK's contribution to CERN.

The balance of £27 million provides the domestic resources for the scientists to carry out their research. It covers salaries and related costs for research and support staff as well as the funds for development work and for such items as travel, equipment and running of experiments. The institute believe that this level of funding is insufficient to secure a proper scientific return on the CERN subscription.

The problem has been exacerbated by the decline in the value of the Pound with respect to the Swiss Franc which has created difficulties in funding the CERN subscription. Over the last five years, for example, the CERN budget has decreased in real terms by 7 per cent to a figure of 938 million SwF. However, in Pounds the UK contribution has increased by 3 per cent to £67 million. Although the Government agreed to protect budgets from such effects, in practice there has been increased pressure to cut back the domestic budget.

Funding is also inadequate in astronomy. Exchange rate problems also apply to the contribution made to the European Space Agency. Here, the amount left for utilisation, after the subscription has been paid, will very soon be quite inadequate to take advantage of the membership subscription. The very recent pegging of this subscription, however, will help.

5. Exploitation of Major Facilities

Use of large international facilities is an essential feature of research in particle physics and has been so for many years. UK physicists continue to exploit such facilities highly effectively. This experience coupled with an infrastructure which is well tuned towards research carried out in this way is already being applied to the planning of experiments for the LHC. Given adequate funding UK physicists will take full advantage of the opportunities for research which the LHC will offer.

6. Management of Large Projects

CERN has been manifestly successful in managing large projects; accelerators have been built within budget, on time and to specification. For projects like the LHC the project leader is directly responsible to the Director General and is a member of the CERN Directorate, the senior management body in CERN. The internal structure of CERN is readily adaptable to meet the needs of such new major projects. Regular reports on progress are made to the CERN Council and its sub-committees where progress and expenditure can be monitored.

CERN has many years of experience in working with industry where the bulk of the equipment for construction of its accelerators is made. In most member states, CERN contracts are regarded by industry as both challenging and prestigious and therefore involve fierce competition. This naturally acts to CERN's advantage in funding its projects. PPARC can help to promote UK industry and encourage it to tender for the many contracts that will be let during the construction of the LHC. Here, at least, the weak Pound will give the UK an advantage.

7. Concluding Remarks

There is little within PPARC's structure and its way of operating that can be criticised at this stage. Looking outside to the new arrangements for funding research in the UK it is important that particle physics and astronomy do not become isolated from other branches of science and from engineering. The PPARC's initiative is establishing a scheme for joint programmes with industry is an excellent way to proceed. Developments at the leading edge of cryogenic technology, image and data processing, high speed data communications and electronics are just a few examples of what will be needed in future.

Letter to the Clerk of the Committe from G A Blair, University of London (14.12.95)

I am writing in order to provide some input into the forthcoming House of Commons Select Committee enquiry into PPARC.

As a recently appointed lecturer in particle physics at Royal Holloway I have a clear interest in ensuring that the funding of my research is sufficient for myself and others, who have devoted much of their early careers to gaining proficiency in the field, to contribute effectively at an international level in particle physics research.

One of my newly acquired responsibilities as a university lecturer is to interview UCAS candidates for places to study physics at degree level. I am very pleasantly encouraged by the fact that a good fraction (more than three quarters of those I have interviewed) have expressed a clear interest in particle physics and/or astronomy. It is obvious to me that the potential to be taught by researchers in these fields, together with the interest in the subjects themselves, is a factor which contributes significantly to the desire of young students to study physics at university. While I take great heart in the fact that the excitement of particle physics and astronomy is instrumental in encouraging our next generation of physicists, I fear that the morale of the researchers who fuel this excitement is being eroded by increasingly tighter funding for the home-based programme.

I would like to stress that the primary reason why young researchers stay in this field, in the face of significantly greater salaries outside of academia, is to carry out the research itself and that this requires a level of basic funding for travel and equipment which has been getting ever more spartan over recent years. This has now reached the stage where British physics are in danger of missing out on leadership roles within the international collaborations purely through being unable to maintain a sufficient presence to contribute pro-actively to the running of the experiment, the physics analysis programmes and the round-table discussions which form a central part of the decision making process. Our international colleagues will be more than happy to take our places.

The recent results from the increased-energy run at the LEP collider at CERN this autumn show again that particle physics continues to provide an exciting frontier research programme, where surprises are always possible and where new ideas are always needed to interpret fresh data. The United Kingdom has played a full part in the construction of the detectors, the running of the experiments and the analysis of the physics data. The potential hints of new physics announced this week at CERN, will require detailed analysis of the data to be taken over the next few years to confirm or exclude the effects seen this year and we must be alert to any other new effects which could well emerge. It is essential that British physicists play a full part in the analysis of the data and the runnigng of the experiments so as to capitalise fully on the investments already made, to pursue their own research interests and to pass their excitement and enthusiasm on to the students in their universities and to the public in general.

I would urge the committee to consider such issues when reviewing the funding of PPARC and to aim to ensure that the people, whose enthusiasm for and dedication to particle physics forms the life-blood of the field, are given sufficient support to continue to hold their own, and indeed to lead, at an international level.

Letter to the Clerk of the Committee from Professor T Sloan, Lancaster University (12.12.95)

Concerning the Inquiry into the Particle Physics and Astronomy Research Council; I am an experimental particle physicist and I have worked for many years at CERN both full time (for three years on unpaid leave from the University) and as a visiting scientist whilst continuing my University duties. I am the head of the Experimental Particle Physics Group at the University of Lancaster. I would like to inform the Select Committee why I strongly support the work of PPARC.

Particle Physics and Astronomy are currently two of the major subjects which are at the frontiers of our understanding. Scientific research proceeds in this way with frontiers defined by the limit of experience and knowledge at the time. For example, in the 19th century Electromagnetism was at the frontier with British Scientists James Clerk Maxwell and Michael Faraday in the vanguard. Early in the 20th century atomic and nuclear physics defined a frontier with Lord Rutherford and his group playing a major role. In the 1930's and 1940's the understanding of the nucleus represented a major frontier with such names as Chadwick and Cockcroft as the leading British Scientists.

Two of today's frontiers are Particle Physics and Astronomy. Furthermore, the two are becoming interlinked since both are needed to explain the history of the Universe starting from the initial big bang. In Particle Physics knowledge has now advanced to the level where we can ask questions about the fundamental building blocks of matter (the so called quarks and leptons). In addition we are beginning to understand the precise nature of the forces between them. Our studies of astronomy have told us much about the Universe now and in the past. This enables us to put the two pictures together to understand how the Universe started from its initial Big Bang and developed to the state which we observe today.

However, there are large gaps in our knowledge with only speculation to fill them. For example, how is the mass of objects generated? Is it due to the Higgs mechanism? It is crucial to answer this question if we are to understand fully the forces between the fundamental particles. A further, crucial question is "Do supersymmetric particles exist and do these represent the majority of the Dark Matter in the Universe?" These ideas represent current theoretical speculation. To be made concrete they must be confirmed experimentally. Without making them concrete the frontier does not advance.

Such experiments need very high energies such as the energies which will be achieved at the Large Hadron Collider (LHC) at CERN. Hence from a scientific point of view the LHC is a crucial accelerator at which to do experiments to answer the next generation of questions which will advance the frontier.

How important is it that the UK continues to participate in such projects? Advances in science have always been made in the developed countries such as the US, Europe and Japan. Such activities I am sure will only continue to be done in advanced countries such as ours. Hence if the questions are to be answered and knowledge to be advanced, it is imperative that the UK continues with these activities. Surely it would signal our decline from leading status if we were to discontinue the activity of pushing back the frontiers of knowledge. Throughout history, man has thirsted for the knowledge which has allowed him to push back these frontiers. Most of this endeavour has been done to explain his surrounding environment and it is the advanced civilisations of the time which have done the wondering and produced the advancements in knowledge. Furthermore, this appeals to young people so that we have a good supply of candidates to do research for the PhD degrees. Such research requires advanced technology and so we provide a pool of trained manpower on various items involving such advanced technology.

Currently the UK scientists are playing leading roles in the designing and building of both proposed experiments for the LHC at CERN. They will thus be in a very good position to exploit these resources when they come on stream.

Concerning the management of international projects; CERN's success as a World leading international particle physicslaboratory has been demonstrated and is universally acclaimed. For this reason the management structure must be about right.

Concerning the structure of PPARC; I find this to be working as well as the old SERC. One improvement I can point to occurs because of the marriage of Particle Physics and Cosmology referred to above. This means that there is a scientific reason to manage the two subject areas jointly.

I hope you find my comments helpful. Please let me know if I can be of further assistance.

Letter to the Clerk of the Committee from Professor Erwin Gabathuler, University of Liverpool (14.12.95)

I am writing to the Select Committee as an active research physicist in Particle Physics responsible for a large experimental group of 60 academic staff, research students and technical staff here in the Physics Department at Liverpool. I have served as a member and Chairman of various research committees of SERC and am currently a member of the Education and Training Panel of PPARC. Previously, I have been Head of the Physics Department responsible for all research and teaching in Physics and have been Head of Experimental Physics Division (3 years) and Director of Research (3 years) at CERN.

The decision to set up the Particle Physics and Astronomy Research Council bringing together like-minded scientists with similar long term research projects in astronomy, planetary science and particle physics was a good one. The scientists have a common goal in endeavouring to understand the origin of the universe and the concepts and principles responsible for the solar system we live in today. The University staff and students plan a very crucial role in designing and building equipment and electronics which is at the cutting edge of technology. The detector components are then put together with our international colleagues to form a large single detector situated at an interaction region of a high energy accelerator (particle physics) or mounted in a telescope or space mission (astronomy). Although our goal is excellence in fundamental science, it is important to realize that we spend a lot of time and resources with advanced UK technological-based industries developing and building equipment.

Our Liverpool group has designed, built and operated six different detectors involving cryogenics, complex data acquisition systems, precision tracking devices (silicon and gas) and high speed electronics since I moved from CERN to Liverpool approximately 10 years ago. In addition, many of our young physicists have been able to spend time at international laboratories (CERN, Geneva and DESY, Hamburg) taking leading roles in analysing physics with their University based colleagues.

However, I am very concerned that we will not be able to maintain that leading international role since I am unable to support my colleagues due to reductions in our domestic budget brought about by the reduction in the value of the pound relative to the Swiss Franc for which we are not fully compensated. In my opinion, an opportunity was missed by the OST to negotiate a reduction in the UK contribution to CERN at the same time as Germany negotiated their reduction in their annual contribution to CERN. The reduction in the domestic research budget is limiting our ability to develop detectors in association with UK industry and in addition, the leading role played by young physicists is under threat which will damage their future career prospects.

We are subsidising our European colleagues to carry out their research in high energy physics through our CERN subscription by our inability to build and operate detectors through the reduction in domestic (UK) funding.

Astronomy & Particle Physics is an exciting subject which attracts school children into science. We attract excellent research students into our subject, and produce PhD's who are well skilled in meeting all the demands placed on them in modern industries. The recent survey of industry carried out by the Education and Training Panel by PIEDA plc (August 1995) supports that view.

Answers to Specific Questions

1. *How important is it that the UK continues to participate in "big science" projects such as the Large Hadron Collider (LHC)?*

The LHC is the only machine in the world to work at the highest energy which brings us closer in time to the physics of the Big Bang. The UK are members of CERN. If we withdraw from CERN which is what the question implies, then we would find it very difficult, if not impossible, to utilise other facilities such a DESY in Hamburg and the new facility BABAR in the US since there is a strong "quid pro quo" among laboratories. The question is equivalent to producing young cricketers and abolishing the possibility of playing for England.

2. *Are UK scientists able fully to exploit this type of collaborative facility?*

UK scientists are fully exploiting facilities such as LEP (CERN) and HERA (DESY). The UK groups have managed to maintain a high profile in HERA physics where are contribution to the experiments was -25 per cent less than that of our European partners. This was achieved mainly through the quality of our physicists and the good will of our European colleagues to accept our smaller contribution. However we cannot expect this situation to carry on into the future especially for LHC. When large collaborations are formed, the ability to contribute to managerial and scientific policy decisions are proportional to the funding support provided by each group.

3. *How should major international projects best be managed and funded?*

The role of CERN is good in this respect, where teams of experienced engineers and physicists from the laboratory and the outside institutes are brought together for a period of construction and later operation. I myself was responsible for a large collaboration of 20 institutes in the European Muon Collaboration experiment on leave of absence from the UK. However, it is essential that outside scientists and engineers take responsibility for periods of three to five years. This ensures that manpower and budgets are always under review and everyone knows what is happening inside the organisation. The system of "Juste Retour" employed by ESA increases the cost of projects unnecessarily.

4. *How appropriate is PPARC's structure for its research portfolio?*

The new structure has only recently been set up. It is working well under the present Chairman and Chief Executive. However, it is important that it does not become remote from the responsible scientists in Universities and from the OST. The present method of funding PPARC and the payment of international subscriptions through the OST still has to be solved. I do not believe it is fair that PPARC should have to reduce the domestic budget, ie the research funding contributions to Universities and hence development in local industry because of factors outside its control.

In 6.17 of the White Paper "Realising Our Potential", it states that the Director General of the Research Councils should bring forward proposals to handle short term fluctuations within the science budget to help PPARC cope with international subscriptions. I do not feel that this has been resolved in a satisfactory manner for PPARC.

The UK has a very strong tradition in Particle Physics and Astronomy. My predecessor here at Liverpool, Professor J Chadwick, discovered the neutron for which he received the Nobel Prize in 1935. I strongly believe in scientists providing value for money in their research, but as the funds for research are reduced in comparison with that of our European and American colleagues, due to whatever reason, then our Nobel Prize winners (a measure of excellence in the subject) will disappear and the subject will wither away. Our bright young enthusiastic students would go abroad to do their graduate studies and few would return to the UK. That would be a waste of resources.

Letter to the Clerk of the Committee from Dr R M Bonnet, European Space Agency (15.12.95)

Having read Press Notice No. 15 of Session 1994-95, released on 19 October 1995, I would be glad if you could accept the submission of the present written evidence regarding PPARC. I have already sent similar comments to Mr Derek Barker (OST) on 7 November 1995 and I do not have any reason to change either their form or their substance.

I will speak solely about the Science Programme of ESA, the field of my competence.

I have seen a drastic change in the transition from SERC to PPARC.

1. The transition from SERC to PPARC was marked by a sudden change in style and policy. There was a sudden change from a regime where the UK had real influence (as, for example, evidenced by the election of a UK SPC Chairman (Southwood) in succession to a UK deputy Chairmanship (Culhane)), to one where the UK delegation has suddenly been isolated. Is this more synonymous with a change in policy rather than with a change of persons? Persons however can make a lot of difference in interfacing with ESA.

2. There has been a lack of co-ordination between PPARC and other departments of the UK government. As an example was the circumstances surrounding the British diplomatic initiative taken immediately prior to the February 1995 SPC meeting. Here a speaking note was delivered at high level to all other ESA Member States' governments. A result was that in several Member States SPC delegates were reprimanded for not having previously reported the results of a technical study referred to in the note. In addition, the British SPC delegate announced that the study was not yet complete. This has done a lot of damage to all parties involved.

3. It is more difficult than before to understand who, between PPARC and the BNSC, has the authority to speak and to determine the space science policy for the UK.

4. In addition, the process through which decisions are being taken in PPARC is complex: between PPARC Council and medium management and the Chief Executive.

5. In particular, the recent problems encountered during the discussion on the Science budget at the ESA Council held in Toulouse at Ministerial level seem to reveal poor financial planning and management.

6. Finally, I find it difficult to see that an organisation such as PPARC, dealing essentially with big scientific issues, which, by definition, rest on a larger technical basis, does not, at least to my knowledge, have real technical expertise in this area.

Turning now to the specific questions, formulated in Press Notice No. 15, I would like to add:

HOW IMPORTANT IS IT THAT THE UK CONTINUES TO PARTICIPATE IN "BIG SCIENCE" PROJECTS SUCH AS THE LHC?

Yes, I believe that it is very important that the UK continues to participate in "big science", projects. I could mention short term, medium term, long term, effects. However, as a scientist and as a European, I would hate to see the immense scientific patrimony and prestige of the UK being squandered.

ARE UK SCIENTISTS ABLE FULLY TO EXPLOIT THIS TYPE OF COLLABORATIVE FACILITY?

As you see, overall, the first year and a half of PPARC representation has not been a good period for British standing in the ESA Science Programme; this is in sharp contrast to the standing of individual scientists in the European community. They are certainly fully able to exploit to the best the facilities provided by the Science Programme of ESA. Unfortunately, not enough resources are allocated to them, and they have not been able to be on board the mission Integral, in spite of the fact that they were very active in the preparatory phase and indeed among the strongest supporters.

HOW SHOULD MAJOR INTERNATIONAL PROJECTS BEST BE MANAGED AND FUNDED?

It would probably be profitable to science if the money for international subscriptions, which have scientific, industrial and political motivations, were separated from the funds which are managed for purely scientific purposes. Otherwise, scientists of other fields will continue to believe that this is science money, which could be used in better ways. Having the scientists shooting at each other is not a worthy objective.

HOW APPROPRIATE IS PPARC'S STRUCTURE FOR ITS RESEARCH PORTFOLIO?

Most of my comments above are intended to answer this question.

I hope you will find these comments useful in the course of your inquiry.

Letter to the Clerk of the Committee from Robert Waugh (14.12.95)

I write in response to the committees request for evidence of PPARC's work and in particular the funding priorities. At present I am a postgraduate student at the University of Glasgow working on the ZEUS detector. DESY, Hamburg. From my ground level preception I would like to give my opinions of PPARC's involvement in the international particle physics experiments.

While working in particle physics I have gained knowledge of both research techniques and my particular field. This, along with a varied technical grounding, will then benefit any future employers and thus myself. As a student I do not believe that I would obtain the same experience and training if the UK was not involved in these large collaborations; in particular the fact that most research students will spend some time living and working in another country.

These benefits will not only help me but also industry and the country from the technical spinoffs gained from scientific research; such as the much reported World Wide Web, an idea developed by CERN. Without this involvement in science research the country would not be able to fully compete in an economic or industrial sense.

Historically, scientists have always forged international cooperation and links, even when political links were all but severed. This is due to the basic principle of research which overrides all others. It is practical to share the cost between member states of a collaboration due to the current world economic climate and the fact that experiments, by nature, are becoming bigger and more expensive. This trend can also be seen throughout industry as companies collaborate in research and development. Leaving such a collaboration is false economy and would cost the country more in lost skills and technology. The need for continued major invovlement is also so we can have an influence in the direction of future research.

At present, we do not produce enough science graduates to fill the economic and industrial need. To combat this I suggest feedback from involved members of PPARC, professors and students alike, to undergraduate and A level students in order to motivate more people into science. I personally believe that particle physics is an amazing, varied and interesting subject and the correct presentation of new research will interest more people not only into particle physics but science in general.

I hope my letter will persuade you that involvement in large projects, such as the Large Hadron Collider (LHC), is justified, not only on a purely scientific basis but also an economic one. If you wish any further clarification of points raised in my letter please contact me through the University of Glasgow.

Letter to the Clerk of the Committee from Professor R. A. Cowley, University of Oxford (12.12.95)

The Physics Department at Oxford University is the largest Physics Department in the UK, producing 170 graduates each year and about 60 doctorates. Approximately one half of the research acitvity is in the area of particle physics and most of this is supported by PPARC. The health of the Department is therefore crucially dependent upon the PPARC programme.

There is no doubt that particle physics and astromomy are two of the areas which are most likely to catch the imagination of those at school considering a career in science and many of our students are attracted because of these programmes. There is also no doubt that research in these areas provides an invaluable training for many careers because the students must use the highest technology, they must learn to work in teams to obtain their results and they usually gain experience of working in laboratories abroad and with scientists from other countries. It is then no surprise that their talents are sought after by many employers and not just in Universities.

I enclose 4 letters from the Heads of the sub-Departments of the Oxford Physics Department describing the work of PPARC in their particular areas: Professor Sir Roger Elliott, Theoretical Physics, Dr G. Myatt, Particle & Nuclear Physics and Professor F W. Taylor, Atmospheric & Oceanic Physics. These letters emphasise the importance of the areas supported by PPARC, the importance of gaining access to international experiments and the importance of a strong UK base to exploit these international links.

I will be pleased to provide further information if it would be helpful.

Letter to the Clerk of the Committee from Professor F W. Taylor, University of Oxford (28.11.95)

I write in response to your notice of 19 October inviting written evidence to the above-named enquiry. In my capacity as Head of a large planetary astronomy group and a major customer of PPARC and its predecessor. I should like to draw the attention of the Committee to the issues in particular.

The first is the balance within the Council of its support to the different scientific areas that fall within its remit. Naturally, I am concerned with the status of planetary science. Most regrettably, the SERC, shortly before its demise, published a plan (“The future direction of UK astronomy, planetary and Earth observation science”; November 1992) which stated that its astronomy committee would treat planetary science as a low priority. There is some evidence that this attitude survives into PPARC. I would urge that the council be advised not to exclude any part of its domain *a priori* in this way, but rather become structured to ensure that the best and most modern science is not compromised by entrenched views or interests.

The second point is the balance of PPARC’s expenditure between facilities, on one hand, and grants to the scientific community who use these facilities (and those who do not), on the other. This is bound to be a major focus of any enquiry. In my view, the subscriptions to CERN and ESA are not really the issue as these are essential. I am concerned, however, that PPARC is investing massively in new ground based conservatories at the expense of other areas, specifically in our case space science and grant support to universities, the latter particularly crucial for the scientific health of the nation following the “DR” shift. We have seen the result of the former in the cancellation of UK science participation in INTEGRAL and a corresponding threat to ROSETTA and other major space science missions, and in the possibility of a slowing down of the whole ESA space science programme.

To a considerable degree, these problems arise because the total budget given to PPARC is not really adequate to cover the contribution of our great nation to such a range of major fields of endeavour. I hope this point also can be examined sympathetically.

Letter to the Clerk of the Committee from Professor Roger Elliott, University of Oxford (6.12.95)

PPARC guides the UK’s main contribution to fundamental research into the nature of matter and the structure of the universe, and the fundamental laws of nature which govern their behaviour. This research is concentrated on the very smallest scale into the nature of elementary particles and their mass, and on the largest scale into the structure of the universe through astronomy. In fact both sets of phenomena are governed by the same fundamental laws. This research is expensive requiring powerful sophisticated apparatus such as the particle accelerators at CERN and telescopes, both land-based and on satellites, which cover the whole electromagnetic spectrum. It is properly a global endeavour to understand these phenomena and therefore most of these projects are international collaborations. A country like the UK, with its rich scientific tradition and its technological base, should surely play a full proportional role in these activities. It is therefore essential that the UK Government continues to accept that Britain should play its proper role in this great human enterprise.

However, this research is not a purely cultural activity. It helps to foster a scientific culture which is essential if this country is to continue to be successful in an increasingly technological world. This is particularly obvious in a department like this one which is responsible for training significant numbers of students in these disciplines. In the first place it is the intellectual challenge of trying to understand the fundamental laws of nature which attracts many of the brightest students to Physics in the first place. We find that an overwhelming number of our applicants, from home and abroad, wish to study and do research in these areas.

Last year we had more than seventy applicants wishing to study here for the D. Phil in particle physics, although we had only two PPARC funded studentships available for those who were qualified. Almost all of these applicants were predicted to get First Class Honours or the equivalent. At the post-doctoral level also the desire to study particle physics is very strong and again, last year, we had more than 100 applicants for two vacant PPARC funded fellowships. These young people provided a high quality pool of talent which helps to maintain the high standard of academic achievement in this country. Of course more start to study in the field than can be absorbed into the academic community and many find their way into other walks of life. In recent years significant numbers of our students have gone to teaching, into research in Government and industrial laboratories, into industrial management, the software industry and the financial sector. They take with them, in addition to their native talent, a training in a rigorous and mathematical discipline which forms a useful basis in many careers.

We therefore hope and believe that PPARC should be encouraged to increase further the numbers of studentships available for Particle Physics and for Astronomy. It will ensure a larger pool of highly intelligent motivated scientists who can use their skills widely in UK Plc.

The sums of money involved to support theoretical work in these areas is relatively small and it should be a protected adjunct to the large sums which it is necessary to spend on the experiments. This is not to say that it should be supported at the expense of the experimental programme. While theoretical speculation is valuble in its own right, it is a description of the actual Universe which is sought, and there must be experiments to discover the actual properties of the system against which theoretical description can be tested. Over many years the budget for ancillary work both experimental and theoretical which is carried out in the UK has been at the mercy of fluctuations in the international subscriptions, caused largely by exchange rate fluctuations. A small variation in the value of the Swiss franc causes changes in the CERN subscription which can completely wipe out the money allocated to the local programme. Although this problem has been slightly alleviated by the new Research Council structure it remains a threat, as is visible this year. The only way in which this is achieved is for the international subscriptions in science to be indexed in full by the Government, as they must be for the country's other international commitments (to say, the UN).

We earnestly hope that the Committee will see fit to recommend that the UK continue to play its role in the important human endeavours which are supported by PPARC, and in particular will seek to find a way to protect a balanced programme from these fluctuations in international subscriptions.

Letter to the Clerk of the Committee from Dr G Myatt, University of Oxford (11.12.95)

VIEWS OF THE SUB-DEPARTMENT OF PARTICLE AND NUCLEAR PHYSICS

It is important that Britain continues to play its part in the scientific endeavours to understand the fundamental nature of our Universe and of the forces within it. The study of particle physics explores one such fundamental area and one in which, over recent years, phenomenal progress has been achieved. The pursuit of this research necessarily implies "big science" and this is the reason why Britain was in the forefront of establishing cooperation on a European level. The success of this approach can be seen by the interest which non-member states of CERN, such as the USA and Japan, are showing in the Large Hadron Collider (LHC).

The current theoretical framework, the "Standard Model", has been very successful in explaining the existing experimental data including the prediction, based on precision LEP data, of the mass of the newly discovered top quark. However there are many mysteries which remain, such as the origin of mass of the elementary particles for which there is no explanation at the present. There are strong indications that the answers to these questions can be found by doing experiments at higher energies than possible with the existing accelerators. A proton-proton collider with the energy of the LHC will therefore be the ideal machine to explore this exciting area and provide answers to the key questions. The results from the LHC will be very important not just in particle physics but also in cosmology as there will be a chance to discover new stable particles which could explain the mystery of the missing mass in the universe.

SERC and PPARC Reviews of particle physics in the UK were carried out in 1991 and updated in 1994 (Particle Physics 2000). The outcome of these reviews was that the LHC at CERN provides the basis for the future of particle physics and participation in LHC should be given the highest priority.

UK physicists are fully able to exploit the type of facilities which have been created at CERN. They have played leading rôles in the LEP experiments and are now doing so in the planning for LHC and its detectors. This UK participation is highly valued by our collaborators, as is shown by the fact that UK physicists occupy a share in the direction of these scientific programmes well in excess of their numerical or financial contribution. It is therefore of the utmost importance that the UK continues to support the LHC programme at a level which allows its physicists to contribute effectively. The document "Particle Physics 2000" outlined a programme of particle physics which was based principally, but not entirely, on the LHC. It was considered important for a balanced programme that a minor component of the funds available be devoted to two other outstanding questions: the origin of the three generations of quarks and leptons, and the nature of the "dark matter" which appears to account for more than 90 per cent of the mass of the universe. In so doing choices were made which meant that the UK would not participate in some other areas of particle physics. If this level of support is maintained, UK physicists can indeed exploit the programme of physics at LHC. Difficult choices have been made and the particle physics community is managing its limited resources with great care and efficiency.

Our experience, and that for example of the Kendrew Review (1983), is that CERN projects are well managed. The technical expertise assembled is outstanding and projects have kept to time and within budget. A major worry for UK physicists in particular is the instability of the CERN subscription £UK, which, since it accounts for three quarters of the Particle Physics budget, has a disproportionate effect on the domestic programme. The nature of particle physics research is that the universities and laboratories in the UK use their resources to develop and construct the novel instrumentation required for the demanding objectives and experimental conditions at the accelerator. Thus although the objective of the research is fundamental physics, the techniques developed are widely applicable. Expertise is built up in the UK laboratories and industry is able to participate in this development by means of PIPSS and ROPA awards and CASE studentships. The technology is passed into industry which is thereby able to compete for orders from CERN and to develop these instruments for use in other areas. An example of this is the silicon microstrip detector in which UK physicists and companies are European leaders. It would be tragic if changes in the UK contribution to CERN were allowed to inflict serious damage to the domestic effort from which the major benefits in technology flow. One of these benefits is the provision of trained manpower. Studies have shown that graduate students trained in particle physics find ready employment in British industry and commerce. In addition to physics ability, employers valued their project management, communication and team working skills.

In order to ensure the desired stability, the particle physics community is therefore in favour of an automatic Treasury supplementation for non-volume changes in the CERN subscription due to exchange rate or GDP variations. This would allow the domestic programme to be planned and carried out in the most effective manner.

Because of the considerable degree of overlap in the scientific objectives (eg study of dark matter) or in the instrumentation involved (eg cryogenic detectors for X-rays and particles) the association of astrophysics and particle physics in a single Research Council seems very appropriate. As particle physics we are anxious that our scientific priorities are directly reflected, and we therefore favour the inclusion of the programme committee (PPC) chairman on Council.

In summary the LHC presents particle physicists with an unprecedented opportunity to study the nature of matter and the forces which bind it. The UK particle physics community has formulated a programme which will allow them to exploit this opportunity, as well as to support a limited programme of first rate projects in other areas. Morale and enthusiasm are high and if these are to lead to success in the construction of the detectors and the pursuit of the research, stability of the funding of the domestic programme is essential.

Memorandum submitted by The United Kingdom Industrial Space Committee (15.12.95)

The UK Industrial Space Committee (UKISC) is the trade association of the UK space industry. The member companies of UKISC wish to bring to the attention of the Inquiry the very major industrial benefits emanating from the space science part of PPARC's activities, particularly those elements of space science undertaken by the European Space Agency (ESA).

In the remainder of this note, the nature of those benefits and the reasons why they occur are outlined, and then some suggestions for the future are offered.

Industrial Benefits of the PPARC Space Science Programme

ESA has been successful in placing in orbit leading edge instrumentation, which has given European space scientists a world leading role in certain areas of space science. By virtue of its mandate, ESA contracts development work to industry, rather than undertaking it in-house. In the early years of its space science programme, ESA played an active systems integration role, but for the past 15 years, industry has been permitted to act as prime contractor for the complete satellite.

The early ESA space science satellites were crucial in giving European industry the capability and credibility to design and build advanced space systems. In recent years, UK industry has continued to benefit by virtue of the leading edge technologies inevitably required by space scientists in their search for better and better performance. The following are just two recent examples from many:

- — a Stirling cycle cooler developed initially with PPARC funding has now been exploited by industry, not only for space science, but also for remote sensing and defence missions;
- — infra-red black body calibration sources based on those initially developed with PPARC (SERC) funding are now being manufactured by industry for environmental monitoring and meteorological space missions, and are being considered for both ground and airborne applications.
- — ground control facilities developed through ESA for space science missions have been commercially exploited by industry and are now controlling more than 20 commercial satellites in orbit.

Besides acting as a source of funding for new and exploitable technologies, UKISC considers that ESA's space science programme is efficient and predictable, and therefore provides a good basis for investment in industrial manpower and facilities.

How Industrial Benefits are Derived from PPARC Space Science

The ESA space science works closely with industry to verify the feasibility of missions proposed by the space scientists, and then investigate and develop any new technology required for the missions. When the technical risks have been reduced to an acceptable level, contracts are placed with industry to design and develop the required space and ground facilities.

Throughout the above process, mechanisms exist to ensure that the science community is aware of the results of industry's activities. Various standing and ad hoc ESA committees, composed of scientists from the ESA member states, monitor and propose changes to the form and content of the ESA and industry activities.

ESA space science missions are selected within a general framework, called Horizon 2000. This framework identifies a number of major missions, defined at the start of the framework exercise by the space science community, complemented by smaller missions which are defined one at a time. We consider that this framework approach has significant benefits for industry, since it provides a long term perspective on the programme, allowing industry to plan its investment decisions with some confidence.

UKISC therefore welcomes the proposed continuation of Horizon 2000 in the form of the so-called Horizon 2000-plus programme.

Future Programmes

UKISC considers that the Space Science Directorate of ESA implements the space science programme in a relatively efficient manner. In pursuit of even greater efficiencies, we welcome the introduction of initiatives to refine the links between the scientists and industry, for example along the lines of the NASA Discovery programme. In the Discovery programme, industry and space scientists together prepare mission proposals for submission to the space agency. At present, ESA selects a new mission based on ideas submitted by scientists and then analysed separately by industry. The Discovery approach fuses the science and industry submissions so that the agency selects from a set of combined industry/science proposals. We believe that this approach offers opportunities for achieving innovative space science results even more cost-effectively than before.

In general, it is desirable for both scientists and industry to shorten the decision and development process of space science missions. Procedures and concepts are required which lead to shorter timescales thereby to reduced costs. UKISC has made a number of detailed proposals for ways to further increase the efficiency of space science missions, and expects to progress these with the ESA Executive during the coming months.

UKISC is not competent to comment on the science objectives embraced by H 2000-plus, but would welcome the inclusion of initiatives to provide more frequent and cheaper flight opportunities—perhaps based on the Discovery approach mentioned above. Increased frequency would improve the continuity between missions, to the benefit of both industry and the space scientists.

We recognise the importance of maintaining a balanced national space science programme to allow UK scientists full exploitation of ESA missions. Coupled with the increased efficiencies of the ESA programme mentioned above, this balance should be achievable with a modest increase in the PPARC space science budget.

To remain viable, Europe's space industry must become more competitive in the global market place. ESA's role as sponsor of industrial competitiveness is laid down in its Convention (article VII.2), but there is wide agreement in industry and government that ESA is failing to implement that particular aspect of the Convention.

UKISC believes that a well structured home market, involving proper procurement practices, can enhance industry's competitiveness. In space, ESA is a major element of the home market. The ESA space science programme can assist industry to prepare for the world market by adopting procurement practices which mirror those prevailing on the world market. Thus, industry should be allowed to provide total turnkey services, not just supply a satellite or a ground facility.

Conclusions

UKISC strongly supports the PPARC space science programme. That programme has delivered important industrial benefits, both direct and indirect, and seems set to continue doing so. The use of ESA as the focus of space science activities is strongly supported, and industry is working with the ESA Executive to further improve the efficiency of the programmes.

Given the important industrial implications of PPARC's space science programme, we would welcome more thorough strategic co-ordination of the PPARC contribution to ESA with that of the other UK bodies which fund ESA.

Memorandum submitted by Logica UK Limited (15.12.95)

INTRODUCTION

Logica is a UK systems and software company with a turnover exceeding £250 million per annum. The company works for large organisations in nearly all segments of the public and private sectors, and about five per cent of our work (ie £13 million per annum) is for space clients. About half of our space work is for the European Space Agency (ESA), and of that, about half (ie about £2-4 million per annum) is funded by the space science programmes of ESA (therefore by PPARC), and about a quarter (thus about £1-2 million) by the ESA infrastructure and general research budgets, thus indirectly supporting space science. Our space science work for ESA stretches back more than 15 years.

The comments below are therefore based on the experience of this involvement in many programmes funded by PPARC.

INDUSTRIAL BENEFITS OF SPACE SCIENCE

The industrial contracts awarded by ESA provide commercially attractive business for Logica. Although invariably the result of international competitive tendering, they have generally provided a reasonable commercial return.

In addition, our ESA space contracts have provided significant ancillary benefits, of which the following are examples:

— *ground control facilities*

Facilities developed for ESA space science missions in the early 1980s have been commercialised by Logica, and sold to operators of commercial satellites, such as Eutelsat and Turksat. The value of these commercial systems sold by Logica exceeds £15 million to date. In general, space science missions are more complex than commercial satellites of the same generation, and therefore stretch the ground control technology more than the commercial missions. The ground control technology and techniques developed for space science missions can then prove relevant to commercial missions of a later generation—this was the model in the 1980s. We anticipate commercialising the facilities recently developed, or under development, for space science missions such as ISO and Cluster, and apply them to commercial missions of the coming decade.

— *high reliability software*

The Huygens probe to Titan, a moon of Saturn, requires ultra-reliable software in its central computer, because once it leaves its American mother-ship near Saturn, it is entirely dependent on that software without any possibility for ground intervention. Huygens is the first European spacecraft to be totally automated in this way—all previous satellites have contained a radio receiver through which instructions could be sent from earth. Logica designed and developed the Hugens software, and the techniques and technology developed for that task are now being applied in other high reliability programmes.

— *image processing software*

In the early 1980s, Logica was contracted by ESA to maintain the image processing software (of American origin) used to treat data from the IUE scientific satellite. That experience made a major contribution to the approach taken by Logica in the development of its Lucid image processing software. Lucid has since been sold in Europe, North America and Australasia into the medical, industrial inspection, defence, broadcasting, remote sensing and scientific markets.

— *project management*

ESA projects present special problems related to international locations, multi-national collaboration, language, complex technology, etc. Such projects have proved a successful training ground for our budding project managers. Several of Logica's senior managers have begun their careers on ESA science projects.

— *staff motivation*

The intellectual challenge of space missions attracts young people like a magnet. Logica can confirm that the level of interest shown by our staff in such missions far exceeds the commercial value of the work involved. Our participation in space science missions helps us to recruit and retain the best and the brightest graduates from British universities.

Given the substantial direct and indirect industrial benefits emanating from ESA space science missions, we welcome the recent decision to largely maintain the level of funding for such missions over the next five years.

NATIONAL VERSUS INTERNATIONAL PROGRAMMES

In recent years, the balance between ESA and national space science projects has tipped more and more towards ESA. On the one hand, the move towards ESA is welcomed because national space science projects seldom if ever lead to contracts with companies such as Logica—the relevant activities are undertaken in

Universities or the CLRC without seeking quotations from industry. By contrast, increases in ESA space science activities give rise to increased opportunities for industrial contracts.

However, we recognise the danger of an imbalance between ESA and national activities. The scientific community must support the ESA programmes, and they will only do so if they have the national resources with which to exploit the systems developed by ESA. We support therefore the need for an active and innovative national space science programme which complements and sponsors that of ESA.

We would, however, like to see ground facilities and software-related activities of national space science programmes contracted to industry. From the information we have seen, we believe that UK industry is at least as cost effective as the CLRC in undertaking such activities. Contracting out such work would enable scientists to concentrate on areas where they can add value to the programmes, rather than duplicating capabilities readily available in industry. Such contracting out would enhance the dialogue between industry and academia, and lead to opportunities for commercialisation of technology, just as it has with ESA contracts.

Technology

ESA undertakes a range of technology developments designed to reduce the risk and cost of future space missions. Up until a few years ago, those technology developments relevant to space science were funded under the ESA Technology Research Programme, which is a mandatory ESA programme and therefore funded on a GNP basis by the member states. Thus UK industry had a fair and equal chance of winning contracts for intersting technology work.

In recent years, ESA has introduced various optional technology programmes. The optional nature of these programmes means that countries can choose to contribute as much or as little funding as they wish. In general, the UK has opted to contribute little if any funding to these programmes.

Increasingly, these optional ESA technology programmes are being used to fund technology relevant to space science programes. Since the UK largely opts out of these technology programmes, UK industry is finding it increasingly difficult to stay abreast of the technology required for future space science missions.

We would welcome a process whereby the decision on the level of UK contribution to each ESA optional technology programme is linked to decisions on space science and other missions, and takes into account the associated industrial implications.

Conclusions

We do not feel qualified to comment on the relative scientific benefits of space science as compared to other science programmes. However, we can strongly confirm that space science has given rise to substantial industrial benefits, direct and indirect. That process is likely to continue, given that space science missions tend to require the most sophisticated available technology.

Logica particularly welcomes the long standing UK decision to focus its space science activities through ESA. ESA contracts its development work to industry and we have been consistently successful in winning more than our fair share of that work. In turn, we have successfully commercialised the experience, techniques and technology used on ESA space science missions and applied them to commercial projects, and not only for space applictions, but also for a wide variety of non-space clients. The technically challenging nature of planned space science missions suggests that similar commercial benefits will be achievable in the future.

Letter to the Clerk of the Committee from Dr Gareth Hughes, Lancaster University (14.12.95)

I have been an experimental particle physicist since 1965 when I started as a D.Phil student in the Nuclear Physics Department at Oxford University. Since then I have been employed at Lancaster University initially as a Research Associate and now as a Reader. I have worked essentially entirely on projects funded by the PPARC or the SERC. This has involved experiments at the Rutherford Laboratory and at the Daresbury Laboratory in the UK, the DESY Laboratory in Hamburg and more recently at CERN in Geneva. The greater part of this time has been spent researching whilst also teaching here at Lancaster, though there have been periods of leave spent at the accelerator laboratories.

I believe that it is very important that the UK continues to be involved in Big Science projects like LEP and the LHC at CERN. Particle Physics and Astronomy are two research frontiers. The two are becoming interlinked in attempting to explain the development of the Universe from the initial big bang. Particle Physics is investigating the fundamental building blocks of matter (quarks and leptons) and the nature of the forces between them. There are many unanswered questions. For example, how is the mass of objects generated? Is it due to the Higgs mechanism? These must be answered experimentally if the frontiers of understanding are to be advanced.

Experiments to investigate these topics require very high energies such as the energies which will be achieved at the Large Hadron Collider (LHC) at CERN. It is a consequence of trying to investigate the structure of matter at the shortest possible distance scales that requires such large, and expensive, accelerators. The present machine, LEP, at CERN has been remarkably successful, it has provided an enormous quantity of new and important information and will continue to do so for the next few years. LEP however is unable to investigate further the effects mentioned above and a new machine is required. Hence from a scientific point of view the LHC is a crucial accelerator at which to do experiments to answer the next generation of questions which will advance the frontier.

Advances in science have always been made in the developed countries. Such activities as Particle Physics will probably only continue to be done in advanced countries such as ours and all the major developed countries are very active in the field. It therefore seems inevitable that the UK would lose its leading status if we were to discontinue the activity of pushing back the frontiers of knowledge. Currently the UK scientists are playing active roles in designing and building of both proposed experiments for the LHC at CERN. They will thus be in a very good position to exploit these resources when they come on stream.

As a university teacher it is clear that Particle Physics and Astronomy or Cosmology are an enormous stimulant to prospective undergraduates.

The UK participation in CERN has been extremely successful. The administration via PPARC is efficient and effective. The support provided by PPARC permits university physicists to participate on an equal footing with international colleagues in large collaborative ventures at both CERN and elsewhere. We are able to contribute to these projects on a broad range of activities. A particular problem in recent years has been the detrimental effect on the domestic research budget caused by Sterling-SwissFranc exchange rate changes.

Memorandum submitted by Dr J C Zarnecki, University of Kent (12.95)

I am writing as a member of the academic community having been involved in Space Research for some 24 years, mostly spent in academia but including three years in the aerospace industry (British Aerospace) as a senior engineer. I am at the moment a principal Investigator (PI) on the ESA/NASA Cassini Huygens mission to Saturn leading an international team providing one of the six experiments on the Huygens probe, the only UK PI on Huygens. My funding is from PPARC so I have significant experience of PPARC (and its predecessors, SERC and SRC).

I would like to take the opportunity to highlight what I believe to be a very significant change in modus operandi of PPARC as compared to its predecessors. As a "middle ranking" member of the scientific community, I found myself playing a part in the decision making process, being a member of the Space Science Programme Board and regularly serving on various ad-hoc assessment panels and so on. The system was far from perfect, in particular, there was an unhealthy emphasis put on producing large quantities of documentation, but at least there was a general feeling, I believe, that the scientific community was involved in the decision making process and that wide range of views was being represented.

However, that has all changed now. Relatively few members of the community are now involved, I acknowledge the greater involvement of members of the business and industrial community. I have no objection to this, but the drastic reduction of community involvement must be detrimental to the health of the system. Even when we are now involved occasionally in an assessment and peer review role, I notice that there are subtle differences. For example, the so-called Rolling Grant Review Panel which used to assess the major grants made to some half dozen University groups involved in space research has been changed so that no academics are involved in the whole process. Individuals, such as myself, are called in to assess one or two of the University groups, but none of us has an overview of the whole picture. This seems to be part of the process in which power to direct research has become far more centralised, and the whole direction of research is vested in the hands of a very few people. This allows personal whims and hunches to become enshrined in policy decisions and seems to be a rather unsafe direction to follow. In addition, the community which PPARC is serving becomes more disaffected and less likely, apart from the few who receive the largesse of PPARC, to take part in the whole research process.

These comments should not be taken to imply an unwillingness to accept a degree of direction in research policy but surely the balance has gone far too far in one direction now. I strongly believe that the new way of operating, which may not be explicit to outside view but is clearly taking place at the working level, is detrimental to the scope and diversity of the research community itself. There is no evidence that the quality of the resultant research has improved accordingly.

One result of this process seems to have been the squeezing of space research by two other areas of 'big science', namely ground-based astronomy and particle physics. In addition, the European Space Agency (ESA) seems to be used by PPARC as whipping boy for the financial problems that the system now faces. ESA is not the cause of our problems, although nobody will pretend that it is a perfect organisation. However, it now provides regular access to the space environment for UK scientists and engineers and gives opportunities for us to become involved in missions which would be impossible for us even to dream of if we were operating as an independent nation or in occasional ad-hoc arrangements (so-called bilaterals). Continued UK involvement in ESA as an active and constructive partner is essential for a nation which takes its science and technology base seriously.

I could make many more comments but as I am sure that the Committee will receive a significant amount of input, I will keep my comments brief.

Letter to the Clerk of the Committee from Professor Ian Halliday, University of Wales, Swansea (14.12.95)

I write as a Council Member of PPARC who has been involved in the funding of Particle Physics since 1987 when I became Chair of the Theory Committee and a Board member of the Nuclear Physics Board of SERC. I have just completed a Prior Options Review of the Royal Observatories on behalf of the Minister for Science and Technology.

I would like to respond on two levels. The first at the level of science and the UK achievements. The second at the level of how this science is funded. In other words the first is a measure of outputs, the second how the inputs are organised.

Since I joined this scientific endeavour in 61 as a research student in theoretical particle physics, first in Edinburgh then Cambridge, the technological capabilities of our experimental colleagues have exploded beyond our wildest dreams. We can now measure the fundamental processes with a precision undreamt of in 1961.

At the same time theory has advanced to such an extent that we have very precise theories of the unified electroweak theory of Salam (Imperial), Weinberg (Texas) and Glashow (Harvard). This Nobel Prize winning theory led Rubbia to get the Nobel prize for the discovery of the W and Z at CERN. The theory of the strong interactions QCD is less precise but is widely believed. Currently computer simulations of a demanding kind are required to extract predictions.

In all of these UK theorists played a major role. The names of Higgs and Kibble spring to mind. The discovery of the Higgs is the Holy Grail of this style of Physics as it underlies all these successes. This is the aim of the LHC whose construction PPARC supported wholeheartedly.

Thus throughout the world wherever fundamental science is discussed UK theorists are seen to be at the leading edge of achievement. This sets a tone for UK achievements which it is hard to estimate but it is large. Moreover there are theoretical ideas whose time will come: Olive (Swansea) duality, the Green (Cambridge) superstring, supersymmetry where a wide set of UK theorists contributed. . . . These ideas are moreover revolutionising pure mathematics.

This is a subject where 1995 UK science stands tall. Given the UK birth certificate of the Higgs our involvement in the LHC is expected. There may well be a Nobel prize for the UK here.

On the experimental side our colleagues are clearly very highly rated at CERN and elsewhere. They work however under a clear handicap. Relative to their European (collaborators/competitors) they have 50 per cent of their resources to contribute to the actual experiments. It is very hard to reach the dominant leadership roles leading to Nobel prizes without resources to back up your ideas.

Within the world of Science PPARC is stigmatised by the ever increasing costs of CERN in deflated pound notes; although the cost in Swiss francs is largely constant. The Government carried out the negotiations over the LHC, claimed a good deal was struck and aimed to put a mechanism in place to absorb currency fluctuations. The latter is in place in the sense that the total science vote absorbs currency movement not just PPARC. However this makes enemies between scientific communities which should be collaborating. It also cuts PPARC off from all possibilities of new initiatives.

Given the damage these currency fluctuations cause both within UK science and more particularly with the continuing rows in Europe, a solution whereby the Treasury, as defender of the pound, accepts the costs for failure to achieve stability seems to many scientists to achieve natural justice. They do not see why their science, almost every year, has to accept turmoil because of Treasury failure.

I believe the structure of PPARC is good for the management of our two parts of basic science. The fact that these two areas of science provide the major motivation for high school students to take up science and engineering make it unfortunate that we are decoupled from Mathematics and other physical sciences.

Finally I would like to stress that PPARC's forebears, in their funding of CERN, funded the development of the World Wide Web. This is at present undoubtedly the commercially most valuable resource produced by UK funded science in the last 20 years. It was the solution to a research driven need. Such efforts have been stopped at CERN due to lack of resources. All the computer scientists did not produce it. This dynamic cannot be overstressed: the research driver as a means of producing new ideas. The magnets which drove Oxford Instruments to growth similarly came out of research need as a driver.

Letter to the Clerk of the Committee from Dr John Hassard, Imperial College Science, Technology and Medicine (12.95)

You have invited comment on the role of particle physics in UK society today, and the role of large scale installations like CERN within the broader research strategy of our country.

I am a particle physicist, with extensive experience of CERN, and, since gaining a DTI Link Photonics grant, some experience of the interaction of particle physics with industrial and medical research. Furthermore, I spent 5 years abroad, at Harvard, and have seen the way the Americans do their research. More recently I have seen how the closure of the SSC has changed things drastically in the US.

In trying to assess the usefulness of "big science", many have looked at the SSC as a model for the LHC. Now the danger of making the comparison will be that people opposed to "big science" will have noticed that the sky did not fall. The bad effects of closing the SSC have not yet worked their way through, and the initial effects we are seeing—drop in recruitment, loss of confidence in the community—are not ones all folk are persuaded by. This is in stark contrast to the SSC propagandists, who made outrageous and inflammatory claims as to the importance of our subject, and in doing so either consciously or unconsciously belittled other people's work. The fact is, however, that the closure of the SSC has affected very adversely indeed student recruitment, and it may well be that many breakthroughs which would have come about won't—but how do you prove that?

The SSC deserved to be cut—not just because of the arrogance of its main boosters. It was exorbitantly pricey, and very badly run. The LHC will be built inside the CERN budget, and offers rather more for a far smaller price.

How can we assess, then, the usefulness or otherwise of particle physics? I used to think that it was incorrect to point to spin-offs—that the beauty and spiritual rewards of particle physics were surely enough to justify it to all but the most philistine, and we could not include the Government in that category. In support of this was the fact that applications might take 10-30 years to come through. For example, quantum mechanics was a result of physics observations made at what was then the Higher Energy frontier. Now it underlies virtually all physical science and much technology: nobody could have predicted its extent, or even existence in the late 1800s. All modern technologies like electronics, lasers, telecommunications, TVs etc are based on and *could not have existed without* the ideas of quantum mechanics.

Furthermore, the whole field of, say, molecular biology, is based on the work of the Braggs *pére et fils,* who were definitely high energy physicists of their day. Unfortunately, say that to a molecular biologist, and he'll start foaming at the mouth. That's because most physicists will ignore the hugely expert work which has gone into exploiting the simple techniques the Braggs introduced. A wonderful and vibrant field has "speciated", and now rightly regards itself as separate. And, since I started working on it, I'd be the first to accept that molecular biology will probably have a greater impact on humans than will physics in the coming years.

Spin-offs usually appear serendipitous, in which fundamental physics, by attempting to do intrinsically difficult things, produces opportunities in other fields, which are seized, and do not appear to be coming from high energy physics, because overlaid there is a huge amount of extra work by specialists in other disciplines and by technologists— but without the particle input could not have been conceived.

Related to this is the simple fact that the time scale under which this all operates is measured in decades. HEP depends on fact electronic, high magnetic fields, enormous data storage and handling—all much more stringent that non-HEP fields. Some random but "immediate" examples of spin-off come from this fact:

— The technologies of the superconducting radiofrequencies and magnet technology adapted and used in power transmission and the solenoids used in, for example, CAT scanners;

— Neutrino detectors requiring ultralight, strong, low radioactive glass, and which appear now to have industrial and optical possibilities.

— Daresbury Lab's advances in mass spectrometry lead to incredibly sensitive A1-26 monitoring in Alzheimer's studies. What used to take three years can now be done in 10 minutes.

— Similarly, Fl-36 in water in Israel allows precise measurement of the Galilean aquifer: the water supply in Israel would be unmonitorable without this technique. One senior Israeli government scientist claimed to me that Israel could not exist without this technique.

— In HEP, the Monecarlo computer simulation technique (EGS) is used in virtually all medical physics applications (one in ten of us facing radiotherapy at one time or another).

— Perhaps HEP's potentially biggest contribution: World Wide Web. My guess is that this idea will underlie *most* computer networks in five years' time.

What about the big question? Why do we need to know arcane things? Well, it was in answering a useless "academic" questions on the seeming unconnected lodestone and electric currents that led Faraday, Maxwell *et al* to develop electromagnetism. In my one meeting with her, Mrs Thatcher said to me that this one discovery amounted to many times (was it "hundreds of times"?) the total market capitalisation of all economies, and she is right.

Some scientists have claimed that particle physics is "cutting down on God's job description." I conclude that while this is surely not the case, it will certainly annoy plenty of people. Others have claimed that our research will allow us "to know the mind of God." I would say this is crassly untrue—as we find out new things, what we do not know becomes more and more apparent, and larger and larger. That sort of statement is not only wrong, but is what brought down the SSC.

To answer your specific points:

— It is vital the UK continues in "big science". However, the exploitation of the science—at very least the dissemination of its implications and discussion of its technologies—should be made a mandatory part of the research process.

- UK scientists can barely exploit what is there. More cash is needed. In return, physicists must spend a greater time in dissemination and exploitation.
- Major international projects can be undertaken within structures like CERN. Regrettably, CERN has a great deal of wastage. I'd prefer salaries and long fixed term appointments at CERN be cut back and there be a greater throughput of established and younger European scientists on shorter contracts. Right now there is too much of a clubbish attitude at CERN. If you know the right people, you can do anything. However, given the scales, the complexities and the goals at stake, it's amazing CERN operates at all.
- PPARC must continue its recognition of the marketplace, and not to be too arrogant of its responsibilities to the tax-payers. We have lots to offer: we should be doing industrial liaison as a matter of course. The alternative is to suffer the fate of the SSC and the US particle physics community.

Letter to the Clerk of the Committee from Dr N Geddes, Rutherford Appleton Laboratory (10.12.95)

I have been a particle physicist for the last 13 years; initially as a graduate student and subsequently as a post-doctoral researcher and Senior Scientific Officer at the Rutherford Appleton Laboratory. I am currently part of the management team for the BaBar experiment, an international collaboration of some 400 physicists, based at Stanford in California.

My own interest in particle physics goes back further than my university days and it was undoubtedly my early encounters with both Particle Physics and Astro-Physics which stimulated my interest in physics in general. It is still true today, in the face of falling numbers of science students, that Universities with strong involvement in both Particle Physics and Astrophysics attract higher numbers of physics applicants than those without this involvement. Interest in physics, and science in general, is clearly stimulated by fundamental research in both fields and this alone is an important reason for the UK to ensure involvement in this increasingly international field.

Only a small proportion of those whose interest is initially awakened by our field will pursue extended careers in it. If I look at where my graduate contemporaries are now, then of seven students at Oxford; two of us have pursued careers in particle physics, while the others are spread between merchant banking, electronics research (industrial) and the computing industry (technical and non-technical). Of my undergraduate contemporaries then a much smaller fraction have pursued academic careers and the spread of chosen professions is much broader. Clearly this is only a snapshot, but I believe that it is indicative of the wide range of careers for which physics training provides a good base. We are also constantly reminded of the need to encourage scientific education in general.

Both Astrophysics and Particle Physics attempt to answer fundamental questions about the universe. We have been extremely successful over recent decades in developing a detailed understanding of many aspects of the world in which we live. Seeking to find answers to questions as varied "what are we made of" or "is the universe finite" is a tradition that reaches back to Aristotle and beyond. Particle and Astro-Physics are both fundamental to these and other questions. Mankind has constantly sought to improve knowledge and understanding of our surroundings. It is this questioning, in part, that makes us what we are. Despite our recent successes there are may important questions that remain to be answered. I personally find particle physics no less exciting than when I first started. Take for example the interest surrounding this weeks announcements from CERN, relating to results at the new energies being reached by the LEP accelerator. It would be tragic indeed if we were to turn our back on this quest.

The Select Committee has been asked to consider whether PPARC should continue to be involved in "Big Science" projects such as the LHC, currently under construction at CERN. My own answer to this has to be a resounding yes. Concentrating upon Particle Physics, my own field of research, then just as Particle Physics is fundamental to our understanding of Physics, then research at the current limits of high energy is fundamental to our understanding of Particle Physics. As we probe deeper and deeper into matter and the forces which control it, or equivalently, further and further back in time towards the Big Bang, then the experiments require higher energies to be successful. Accelerating particles to very high energies requires large and expensive facilities. These facilities inevitably become major international collaborations. It is worth remembering, however, that although the energies attained by the most powerful of today's accelerators is several hundred times that achievable only 30 years ago, the cost of, for example, the CERN laboratory has not increased in real terms. If British particle physicists are to be involved in frontier research then it is essential that the UK maintain an involvement in these projects. Such involvement should not, however, be at the expense of all other aspects of the particle physics programme. There is an important place for smaller (though still involving large international collaboration) projects such as those currently being proposed to study dark matter, CP violation and neutrino oscillations. The importance of maintaining the breadth of the particle physics programme over the coming decade was addressed in the report "Particle Physics 2000" published by the SERC shortly before the creation of PPARC.

This latter point is related to another question before the committee. Namely whether UK physicists can benefit fully from our involvement in organisations such as CERN. This is clearly becoming increasingly difficult. Throughout my involvement in Particle Physics, the field has seen continued pressure on domestic funding. A large part of this problem has been the growth and continuing uncertainty in the subscriptions to international bodies such as CERN. The UK CERN subscription is fixed in Swiss Francs and is determined by a formula agreed at governmental level. As a result of economic consequences completely outside the control of PPARC this subscription, though falling in Swiss Francs, has grown in pounds. Recent weakness of Sterling against the Swiss Franc have meant large year to year increases in the UK CERN subscription of close to 10 per cent of the total PPARC particle Physics budget. More crucially this is 20 per cent of the domstic spend on particle physics. Unlike most other CERN member states the UK insists that the CERN subscription is paid directly from the science budget, with no account taken of the effect of factors such as exchange rate fluctuations. The absolute value of these fluctuations is to a large extent determined by government economic policy and is very small in term of the total government spend, but it is a huge fraction of the PPARC budget. In recent years it has become increasingly difficult to absorb these fluctuations, which inevitably appear to be in the "wrong" direction, without significantly affecting our ability to collaborate effectively with our international partners.

The final question before the committee relates to the management of the PPARC program. In my experience, the particle physics program is managed very effectively. The administrative overhead for PPARC compares well with other research councils. PPARC doubtless benefits from its focused nature, concentrating on only two, closely related, disciplines. The central administration of the particle physics program through the Rutherford Appleton Laboratory has proved very effective, allowing efficient and responsive deployment of limited and shrinking resources. The effectiveness of this approach is recognised by our colleagues in UK universities and is often envied by our international collaborators. One consequence of the formation of PPARC, however, was a general uncertainty of exactly how the new council would function, for example, with regard to the evaluation/approval of new research proposals. It was not clear for some time how or whether the committee and peer review system operated by the SERC would continue to operate. I think that there is still a large degree of uncertainty in this regard and in many cases it is still not clear exactly what role all aspects/committees/executives of the council fulfill. My own experiment (BaBar) has faced and continues to face this problem first hand, being one of the first completely new projects proposed under the new council structure.

In conclusion, I believe that the physics supported by PPARC is of crucial importance in our understanding of the universe. As such it acts as an important stimulus to the study of physics and other science based subjects. The ability to attract some of our brightest young people into these subject areas will be of crucial importance to the UK in the increasingly technical world in which we find ourselves. PPARC provides an effective and efficient management for the projects it covers, despite some initial uncertainties about how it would actually function. The UK should continue to be involved in the "Big Science" projects required by Particle and Astro-physics research, but clearly the growing problems we currently face in our exploitation of these projects must be addressed. In particular our current vulnerability to economic factors completely outside our control must be reduced.

I would be happy to expand on any of the points made above. The opinions expressed above are entirely my own and do not represent the views of my employer, the Rutherford Appleton Laboratory.

Memorandom submitted to the Royal Society (20.12.95)

That you for inviting our input to your inquiry into the Particle Physics and Astronomy Research Council. The following submission has been endorsed by the Council of the Royal Society.

As you mention in your press notice the Research Councils have only recently been restructured. We believe that each Research Council has endeavoured to put in place a management structure that best meets the needs of its particular mission. PPARC, having been split off from the former SERC, has undergone radical change.

We believe it is premature to make judgements concerning its structure and operation; these need time to settle down and PPARC's client communities need time to adapt or react to them.

Following the Research Councils' reorganisation, PPARC has acquired a portfolio almost entirely composed of basic science. As the White Paper recognised, the PPARC mission must be justified primarily in terms of the intrinsic value of basic science. Nevertheless, the formation of its Industrial Liaison Panel and the launching of the PPARC Industrial Programme Support Scheme (PIPPS) in 1994 do point up the relevance of PPARC's activities to industry.

The importance of the output of PPARC's activities—world class basic science—must be recognised. In many areas of particle physics and astronomy the UK gives world leadership. This depends critically on long-term investment. Exciting current activities, such as the Large Hadron Collider, the Infrared Satellite Observatory, the Hubble Space Telescope and the Gemini ground-based astronomy project stem from investments made 10-15 years ago. The UK's involvement in future world-class activities depends on the investments it chooses to make now.

Much of today's leading-edge research in particular physics and astronomy is carried out through (sometimes large) multinational collaborations. As well as being able to draw on international expertise these collaborations also allow participation in programmes that would be beyond the funding capabilities of individual nations. These are important collaborations, recognised as such by PPARC which, as you point out, invests in them some 54 per cent of its total expenditure. The UK should, where possible, actively encourage international collaborative facilities to be located on its own soil.

The UK's domestic science base must be strong enough that its scientists are welcomed into these collaborations. For them to take part fully the UK must invest so that membership dues are met and there is sufficient additional funding to meet the costs of UK participation in the experimental programme. Reducing this funding to make savings and thus reduce UK scientists' ability to participate would be counter-productive. If savings are required, rather than reduce the UK's investment the management and organisation of these international collaborations should be kept under scrutiny and savings in their administrative costs sought where appropriate.

The disciplines supported by PPARC have a long tradition of commitment to promoting public understanding of science. This remains one of the strengths of the PPARC community.

I hope these comments are helpful and I look forward to seeing your report in due course.

Letter to Mrs Anne Campbell MP from Dr Paul Murdin (2.11.95)

INVESTIGATION OF THE PARTICLE PHYSICS AND ASTRONOMY RESEARCH COUNCIL (PPARC)

I would like to express some opinions on the affairs of the PPARC, since you are not only a member of the Committee on Science and Technology making the investigation recently announced, but also my MP. I should say at the outset that I am a member of the staff of PPARC at Swindon (I am the Head of Astronomy) and I am also seconded into the British National Space Centre in London for a few days per week as the Director of Science, with particular responsibility for the PPARC's policy towards the European Space Agency's (ESA's) science programme. Of course, I write in a personal capacity, as a British scientist.

BRITISH ASTRONOMY A SUCCESS

I was formerly a research astronomer (at Royal Greenwich Observatory in Cambridge, at the Royal Observatory Edinburgh, and elsewhere overseas—USA, Australia, Canaries). I believe that astronomy as practised in the UK is of an outstanding international quality, and recognised as such. I believe that astronomy is worth funding because it is culturally necessary, because it attracts excellent people to science, and because it inspires the people of Britain. I think Britain, and British life (including industry and the technological base of Britain) would be poorer without astronomy. I do my best to play to these aims and themes when I broadcast about astronomy and arrange for British astronomy discoveries to be widely known. I believe that astronomy has been, and, in spite of everything, remains, a British success story—under difficulties.

THE CHANGE IN THE PRACTICE OF ASTRONOMY—MORE SPENT OVERSEAS

In broad terms, the UK's funding for astronomy (including space science) has been constant in purchasing power for at least a decade, and (I anticipate) will remain so in the next few years. In the same period, the practice of astronomy at an international standard has more and more relied on space satellites, purchased through ESA membership, and on telescopes on clear mountain tops, particularly La Palma and Hawaii.

The telescopes are operated through money paid overseas, of course. The ESA money is also spent in ESA's technological establishments outside UK, or it is returned to the UK through industrial contracts, for example to Matra Marconi (formerly British Aerospace) and other high tech industries. Almost no ESA money comes back to academic institutes. The expectation is that each ESA Member States will support its own institutes properly in order to contribute to the success of the ESA Space Science Programme. I will explain why the UK doesn't do this.

LESS SPENT IN UK . . .

As a consequence of the above trends, a greater and greater fraction of astronomy's constant budget is being spent outside the UK or in UK industry. This means that less and less is spent on astronomy in Britain, in the UK's universities and institutes.

. . . BUT GREATER DEMAND

At the same time, universities are creating astronomy departments, because they are now market-driven and they know that undergraduates want to study astronomy—the number of undergraduates has risen by several tens of percent in the last decade and, although the number of physics students has remained constant, the number studying astronomy has doubled in eight years. Moreover, eveyone's expectations have risen; you can measure this by the rise in the GDP by 30 per cent in the last decade.

IMBALANCE

In summary, over a ten year period, demand in the UK for astronomy (at the university level) has doubled relative to the supply of resources for PPARC (and its predecessor SERC).

This is the fundamental reason why astronomy as managed by PPARC is having trouble.

THE DECLINE OF UK FUNDING IN ASTRONOMY

As a result of this growing imbalance, more and more astronomers in universities and institutes in UK are chasing less and less money. Too often, they are arguing about what should be shut, and they can't agree because everything has been so pressured that there is no fat left to trim, so there are always good reasons not to shut something that is proposed to be shut. The difficulties now are such that we have to face closing (or at least reducing drastically) whole institutes; this is why there is such a threat to the Royal Greenwich Observatory in Cambridge, about which no doubt you are receiving lobbying—but, nothing personal, there's an equal threat to the Royal Observatory Edinburgh, and the astronomy groups at the Rutherford Appleton Laboratory.

Often, too, astronomers are bad tempered with PPARC because their applications for money are turned down—the truth is that there isn't enough money to go round, but we are reasonable people and we try to give reasons for turning people down, and these reasons are not very good, so people see through and don't accept them.

We are sometimes poor partners to our European colleagues, because we are tight fisted, and we have to give reasons for this too, which our partners find difficult to accept, eg the Integral debacle earlier this year, when we withdrew from participation in this ESA mission at short notice—incidentally, ruining the careers of a group of astronomers in Southampton, and blighting the careers of another group in Birmingham. Some of our well-financed European science colleagues find it difficult to understand why we have been putting such pressure on ESA's finances recently—although, here, I feel that ESA is justifiably subject to valid criticism as an inefficient organisation which badly needs a shake-up (and we have found people who share this opinion throughout Europe).

PPARC MANAGING THE GRACEFUL DECLINE OF BRITISH ASTRONOMY—AND THE ALTERNATIVE

In the short time that PPARC has been in existence, under the new management, we have been grappling with the problem of managing the money which is available, which is too small for what we are set to do, in the programme which we have inherited from SERC. Our policy is in effect to stabilise and consolidate a smaller British astronomy activity.

Of course I know that astronomy is a luxury compared with, say, the NHS; but at some level, in a balanced world, some expenditure on British astronomy is right, especially if astronomy is a British success story and a strength which we can play to. The nature of the science means that it is expensive and run overseas. If, as I suggest we do, Britain needs to support astronomy, we need to support properly both the overseas components of the science and the British side.

PPARC is being forced towards the direction of making rational the reduction of the British component of astronomy. The alternative is to put more towards the British component.

This is my analysis of the underlying situation, having lived with it throughout my career, and intimately for the last two years. It is a political problem to decide what to do about it, and that, I suppose, is what you are tackling. I urge you and the Science and Technology Committee to do something to arrest the decline.

I would be glad to provide further information, or take the issues further with you.

Further letter to Mrs Anne Campbell, MP from Dr Paul Murdin (25.11.95)

Thank you very much for your sympathetic letter of 22 November responding to mine of 2 November about the Select Committee on Science and Technology's enquiry into PPARC.

I wasn't in my letter trying to make the case for scientific research in general. Your own connection with science and technology will give you a practical insight into the necessity for scientific research. It is the only way that it will be possible to survive in modern times, at least according to the standard which we now set for ourselves. I was trying to set out the place of astronomy in science in public life.

Astronomy's great value (to my mind) is that it produces people who do achieve things, by motivating them. As I mentioned in a letter to the Independent last year, I heard Rajiv Ghandi say much the same thing in a speech in Delhi in the mid 1980's. "Why does India sponsor astronomical research?" he asked rhetorically. "You can tell a peasant farmer to plant his seeds at such a separation, at such a time, and water every so often. He might follow the instruction or he might not. Will he believe in what he is told, as science? Will he apply the same principles of experiment, measurement, repetition and analysis to his cows and to his well? No—he has to be inspired, he has to become confident, he has to adapt his mind to a scientific way of working. India's achievements in astronomy and the space programme are visible signs that India is a scientific country, in charge of its future. They are meant to inspire our peasants to become scientific."

I feel we can read across from this into our own culture, by showing the British public that we are a capable country, developing sophisticated devices, part of a magnificent global enterprise, part of the destiny of mankind, learning its place, investigating its origins. We have a lot of achievements in British astronomy, some of which in space I have been broadcasting about repeatedly in the last weeks. Whether we reach 95 per cent of the public as you suggest we should, or whether we reach only 25 per cent, the people whom we do reach really matter to Britain; I am relying on some of them to pay my pension in a few years time, and this is one reason why I am working to galvanise them!

PPARC has some evidence that this is working: a large fraction of physics degree course entrants mention astronomy as their early introduction to physics. The number of undergraduates enrolling for astronomy or physics and astronomy courses has doubled in the last decade, whereas the enrollment for physics has slightly fallen. In terms of the PhD recipients that PPARC sponsors, essentially none remain unemployed and there is some evidence from UCL that they get jobs earlier than their colleagues in more general physics courses. PPARC has just published a report on the numbers, career paths and quality of its PhD students. Three quarters are in non-astronomy jobs after a few years. This all goes to show that astronomy produces the excellent people that I spoke of.

Although I think that people are the most important of astronomy's outputs, nevertheless, astronomy does produce spinoff into practical life and you ask me for ideas about this. Here are some from a variety of my experience.

I myself while Director of the Royal Observatory Edinburgh initiated a project called PRISM, which is currently successfully under way, sponsored by PPARC, EPSRC, the Scottish Office and the NHS, which is likely to transfer an astromomical project analysing photographs of stars into one which analyses mammograms for signs of breast cancer, with greater reliabilty and less cost than the current breast cancer screening programme.

The European Space Agency and NASA are just about to launch a space satellite SOHO to study the Sun. Britain is part of this enterprise (we have bought in to a $1 billion project for about £40 million). As a star, the Sun is surely the only natural fusion reactor we can study in detail. We know enough to know we don't properly understand the process and we are not sure whether the deficiency is in our knowledge of the Sun or of the theoretical processes. Information from SOHO will help decide; Douglas Gough at the Institute of Astronomy on Madingley Road is an investigator on this mission. Why is this important? Fusion is the most likely source of energy which can be used to replace fossil burning when fossil fuel runs out in a century or so. In Oxfordshire the JET project is trying to replicate fusion in a reactor. How can we hope to engineer an industrial reactor when we don't seem to understand the only natural fusion reactor?

Maximum entropy analysis is a way of data analysis used to make pictures more precise. Eg to read the blurry licence plate on a photograph of a speeding car. The method is finding industrial applications through a consultancy set up by Steve Gull, formerly a Cambridge radio astronomer. Incidentally, a black Cambridge radio astronomer who returned to South Africa and became prominent in the trade union movement is currently in charge of development in South Africa for the ANC; I forget his name.

Craig Mackay, a Cambridge astronomer, learned how to make CCD detectors for astronomy. His company AstroMed in the Science Park is making them for medical purposes.

American Science and Engineering (AS&E) developed X-ray detectors for X-ray astronomy satellites. When you pass through security at an airport you are very likely to find AS&E's name on the side of the X-ray machine.

Chris Rapley at the Mullard Space Science Laboratory in Dorking, Surrey is using astronomical image processing tecniques on images from space of geological formations. These have been used by exploration companies interested in where oil might be located in Antarctica.

An attitude control system developed by British AeroSpace in Bristol for an astronomical satellite has become a standard system for use in industrial space applications. A cryogenic system made by Rutherford Appleton Laboratory for a similar purpose is being developed by BAe for industrial applications. Colin Pillinger at the Open University has initiated through RAL the development of a miniaturised gas anlyser for use in a future space mission, landing it on a comet to analyse its composition: this has industrial possibilities for field use.

I hope these examples are interesting to you—dare I say inspiring?

Letter to the Clerk of the Committee from Professor T. Jones, University of Leicester (2.1.96)

I have been asked to comment on the activities of the Partical Physics and Astronomy Research Council which funds a major part of the research activity in this Department. The Physics and Astronomy Department at Leicester has strong groups in astronomy, x-ray astronomy and ionospheric/magnetospheric physics. All three programmes are supported by rolling grants and the current value of these grants is in excess of £12M. The members of the Department have therefore had first-hand experience of the PPARC operations during its initial period of activity.

The main comments that I have received from members of staff are as follows:

1. The concentration of "Big Science" into one research council is regarded as being very successful and is already producing some benefits through rationalisation of the programmes.
2. The large drain on PPARC resources due to the subscriptions of ESA and CERN are thought to be extremely damaging to the programme, in that funds are siphoned away from the the national programme, sometimes in a manner not fully under PPARC control. Some method of constraining these subscriptions charges is clearly needed.
3. There is an unquestioned need for large international facilities and both the Astronomy and Geophysics groups in this Department make extensive use of these, for example the Le Palma telescopes and the EISCAT radars. The very considerable efforts that PPARC has made in maintaining the UK activity in these major projects is very much appreciated as without access to world-class facilities it is unlikely that the UK could compete internationally at the level it now does.
4. It appears that some savings could be made in the management and operation of these large facilities if more direct involvement of the university groups becomes a possibility eg trained operators from the University sector could replace, on a campaign basis, some of the expensive permanent staff currently funded at these facilities. This is not to suggest that we would wish to see reduced participation in any major international projects.
5. The PPARC committee structure is still developing and there have been no major criticisms up to this point in time. There have been minor criticisms of the detailed briefing of some committees which could, perhaps, have been more clearly focused.
6. There is great satisfaction with the helpfulness of the PPARC office staff at Swindon who are readily accessible and are willing to listen to the community's views. Excellent advice regarding the technicalities for the application and administration of grants is readily available. It is felt that the peer review system needs some strengthening, particularly in some of the minority subjects areas.
7. PPARC staff have been involved in a number of very successful new initiatives eg the new initiative on the Public Understanding of Science and Technology. Considerable efforts have been made by PPARC staff in developing some of these concepts which will undoubtedly stimulate interest in this area of science.
8. All members of the Department wish to congratulate PPARC on the very smooth transition from the old SERC structures to those now in place. This change was extremely smooth and did not create any disruption to the Department's research programmes, such as those which occurred in the EPSRC areas. It is generally felt that PPARC is responding well to new problems as they occur eg the creation of new research studentships to cope with the transition from the three-year BSc degree to the four-year MPhys degree as the normal entry point to the PhD programme.
9. The distribution of PPARC studentships appears to be directed towards large research groups and this is regarded as good use of scarce resources. There is more concern in the way CASE awards have been handled since these have been tied to projects which are believed to produce an immediate industrial product. The relationship between PPARC and industry is not yet quite right and there appears to be too much emphasis on immediate short-term returns and too little on longer term strategic support of new technologies.
10. It is clear that the area of science represented by PPARC has a major influence on the number and quality of the undergraduate students recruited by this Department. Our Physics with Astrophysics and Physics with Space Science and Technology courses invariably attract better quality students and in greater numbers than our straight physics degree course. This is undoubtedly due to the attractiveness to university entrants of "Big Science".
11. The subject areas covered by PPARC attract very able research students to our PhD degree programme. These students are generally successful in completing their PhDs and the drop-out rate is low. The job prospects for PhD graduates are no worse than any other areas of physics. Numeracy and the ability to handle the large data sets are seen to be valuable skills which are learned in the PPARC disciplines.

In conclusion, there is great satisfaction in the way PPARC has developed and with the way in which its management structure has evolved. The enthusiasm and leadership shown by the PPARC Chairman and the Chief Executive has been an extremely important factor in the success of this new Research Council.

Memorandum submitted by Dr J Röttger, Director, EISCAT (4.1.96)

The EISCAT Scientific Association was established in 1975 as an international institution for the studies of the high latitude Earth's atmosphere using the ground-based method of incoherent scatter radar. The Association is funded by research councils and academies in the six European countries Finland, France, Gemany, Norway, Sweden and the UK. The partner in the UK is the PPARC. The operation of the

Association is governed by a Council, a Scientific Advisory Committee and an Administrative and Finance Committee with members from the partner countries. The chief executive of EISCAT, the Director, receives guidance and advice from and is supervised by the Council and the Committees. The operation of EISCAT takes place in Finland, Norway and Sweden.

This consultation has proven to be a very productive international collaboration. This holds for the administrative, the scientific as well as the operational part. It has increased the mutual understanding of administrative procedures of the different partner countries, the scientific collaboration and the operational competence. It has opened access for a wide scientific community to a research area, which would have been impossible to achieve by a single country. The international conferences, held on research disciplines associated with EISCAT, prove the high standard of this research as well as the growing number of competent users, amongst them many students and younger scientists.

It is obvious that the scientific community of the UK has made very organised and highly efficient use of the EISCAT research facilities. The UK is also forcefully supporting the new facility which EISCAT will inaugurate this year on Svalbard.

The structure and dynamic development of IESCAT has been used widely as a relevant example for international scientific cooperation, advanced technology, innovative processing techniques, resulting in a competent center of excellence. Proposals for similar research facilities have been considered for instance by the National Science Foundation of the US, arguing that their rersearch directions and advanced technology need to follow this European example. A proposal for an international center for equatorial atmosphere research in East Asia has used the international EISCAT orginizational structure as a basis for their possible organization. More recently Japan had applied to become a member in EISCAT, noticing the efficient way of international scientific cooperation. It was now agreed that Japan will become a member of the EISCAT Scientific Association on 1 April 1996.

It is unquestionable that the scientific research using the EISCAT facilities has gained improved understanding of the solar-terrestrial environment. It is in particular noticeable that the ground-based observations with EISCAT are an indispensable support for the space-borne observations of the Earth's atmosphere, ionosphere and its coupling with the geo-space environment. The understanding of envirionmental questions and problems can only be solved by the collaboration of several research paths, such as ground-based, space-borne as well as theory, modelling and computer simulations. EISCAT is tied in to all these directions.

Letter to the Clerk of the Committee from Professor Michael Bode (6.1.96)

I am writing to you to express the views of the Liverpool John Moores University Astrophysics Group concerning your request for evidence relating to the above inquiry.

In the short time that it has been established, we believe that the PPARC has striven successfully to fulfil its mission, which of necessity is different from those of the other research councils. We would hope that the Committee will recognise the need to pursue basic science with vigour. Its endeavours are among those for which our civilization will largely be remembered and its impact in both the short and long term is unequalled. Astronomy in particular is one area in which the United Kingdom has a record of nearly 400 years of excellence and which has a thriving, young community involved in some of the world's largest and most significant projects. As well as its contribution to the general furtherance of knowledge, astronomy is important in several other ways which we believe PPARC is exploiting in a far more co-ordinated way than its predecessor, SERC.

There is no doubt that there is a public fascination with astronomy and space research that transcends almost any other field. Many of today's scientists were attracted to their chosen careers through an initial interest in these topics. PPARC, we believe, is making great effort to assist in the furtherance of the Public Understanding of Science & Technology initiative which is vital to ensuring that the UK remains a first rank technological nation.

Astronomy and astrophysics provide an excellent training for our young people in state-of-the-art technology, physical concepts and mathematical modelling, both at undergraduate and postgraduate levels. PPARC is of course a source of much of the UK's astronomical postgraduate infrastructure. It was gratifying to learn of the recently commissioned report which concluded that such postgraduates are highly employable.

We are also pleased to see the attention PPARC is paying to industrial liaison. In the past a great deal has been said about direct spin-off. Now there are many tangible examples and the research council is seen to be very active in this area.

Our main concern is that funds for open competition, where some of the most innovative ideas are pursued (largely through the grants line), do not continue to be squeezed by our ESA and CERN subscriptions. Although commendable progress has been made, particularly in relation to the former area, we are still seeing pressure from all sides to cut programmes. Often this is at the few percent level each time, but any lean there was has now gone and vast amounts of time are now spent in committees arguing over where such cuts will do the least damage. If there is any way of further decoupling our international subscriptions to leave our core programmes less vulnerable then this should be seized upon.

In summary, we have much to be proud of in the area of astronomy and astrophysics in the UK. The community is generally well supported by PPARC within the inevitable funding constraints. The research council has grasped the nettle of meeting its obligations in PUST and industrial collaboration. We are, however, concerned at the diminishing amount of funding available to fund new initiatives, particularly through the grants line.

Letter to the Clerk of the Committee from Dr Sue Ion (8.1.96)

HOUSE OF COMMONS SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY INQUIRY INTO PPARC

As member of Council of PPARC, I am aware of the Council's Memorandum to the Committee and noted that the deadline for submission of written evidence to the Committee had been extended.

I fully support the submission made and do not wish to repeat the extensive commentary provided by the Council's Executive, but feel that I would like to emphasise one or two points from the point of view of Industry drawing on my own experience. Large complex projects often decades in duration, are a feature of the nuclear industry in which I work, as increasingly is the need for international collaboration with the attendant challenges this brings. There are a number of parallels therefore in what I experience within my role as Technology Development Director BNFI, and what I have observed as a member of Council.

The Council's submission makes the points that Astronomy and Particle Physics touch the public imagination in a way few other sciences do (witness the number of popular books on these subjects). As a result an interest in Astronomy and Particle Physics are the usual routes into the physical sciences for young people and often attract many of the best young brains we have by the very nature of the projects they drive, their intellectual challenge, their complexity, their difficulty.

PPARC's programmes are geared towards curiosity driven big science, which is as it should be, and wholly compatible with the Council's mission. Although wealth creation does not figure as a key driver, in fact the investment made in big science does yield many opportunities for wealth creation in the short and medium term as well as much longer term. Pure science of the type supported by PPARC is a key technology driver by putting extreme demands on it to develop faster—much faster than would be the case with the demands that industry could put on it which are often bounded by the possible.

My own Company has benefited from research sponsored in times past by both particle physics and astronomy programmes requiring sophisticated radiation sensors and radiation hardened detectors. These devices are now being further developed by BNFL for application in nuclear waste management and clean up programmes.

The nature of PPARC projects means they demand highly trained, clever, scientists and engineers, used to designing, developing and operating high tech kit and computing at the forefront. These type of people are highly valuable to Industry long term. PPARC projects demand team working and excellent communications utilising the most up to date methods and systems again highly valuable for Industry looking to evolve or better still leap into the 21st century. I can confirm that ex PPARC sponsored students have been recruited by BNFL and found to be excellent contributors.

PPARC projects also require equipment and engineering support from Industry of the highest calibre. UK companies benefit both in supplying key components and devices at the forefront of current technology and by participating in development at the frontiers of what is possible thereby increasing their potential for spin off and wider industrial exploitation long term as explained above.

The willingness to participate in curiosity driven "big science" is one of the hallmarks of a strong society. The UK is the founding nation of all the sciences in the PPARC portfolio. Leading the world in these areas is a national tradition aspects of which should be maintained.

The question remains "what should the level of the investment be?" There is no doubt that research into the issues at the heart of PPARC's portfolio is expensive, and getting more so. As little as a few decades ago it was possible to make giant leaps forward in our knowledge and understanding with fairly modest capital expenditure. Now some programmes in Particle Physics and Space Science are so sophisticated that disregarding future not insignificant operating costs, they require major capital investment in facilities and equipment to then enable a portfolio of experiments to be executed over many years. This can only be achieved with international collaboration on a significant scale.

Council's submission, emphasises rightly the importance of international collaboration but cautions that the percentage of the budget which is pre-committed annually as a result is already having a significant detrimental effect on our domestic programmes and Council's ability to fund new exciting work proposed by UK researchers. Simplistically I would liken it to paying an expensive membership fee of a health club only to find I couldn't afford the few pounds court fee and racket rental each time I wanted to play squash. There is no point paying massive subscription fees to be members of CERN or ESA if UK researchers can't activily participate in the programmes made possible by investment in these organisations. In my view this problem must be addressed and I fully agree with Council's recommendation that the percentage budget committed to international subscriptions should be capped at 50 per cent. This goal cannot be achieved without

Government and OST support. Whilst every attempt must and will be made to secure maximum efficiency and effectiveness in the ways these collaborations are structured and operated, nevertheless, relatively small increases in the domestic programmes will be required to enable the benefits to be realised of the considerable investments made and ongoing e.g., in ESA and CERN.

One final point I would wish to make is that there are more good research projects which could qualify for sponsorship than there is cash available to fund them from PPARC's allocation. This on one hand is good as it means that there is competition and hence a striving for excellence in both the quality of the science and its project management, on the other hand it means Council (on behalf of the UK) has some stark choices to make in the future. Should the UK spend more on Astronomy (space or ground based) and less on Particle Physics or vice versa? It would have to be recognised that if Council's only course of action was to shift funds in this way, then it would have a very severe and long term impact on UK standing and the strength of the academic community in the area affected.

In making judgements within Industry on widely differing technology with apparently similar excellence in quality of science I would argue that the decisions are "easier" because the final judgement can be based on assessed business benefit or potential. Within my own Company we do this as a matter of course even for long term programmes. For the programmes sponsored by PPARC where wealth creation is not the primary driver, other means to assess between competing claims of excellence/worth to the nation as a whole, will have to be brought to bear if no new money is available. Within Council over the coming months, the members I am sure will be grappling with these challenges.

Please feel free to contact me again if you feel I can help further.

Letter to the Clerk of the Committee from the European Space Agency (13.2.96)

I make reference to your letter dated 31 January 1996 which you addressed to our Director General, Mr. Jean-Marie Luton.

As regards the questions you raised I consider that most of the required information is readily available in London at our governing body in the U.K., the British National Space Centre (BNSC).

In order to provide you, however, with some quick answers I am attaching document ESA/C-M(95)5 which summarises the Agency's proposals for its Long Term Programme as presented during the Toulouse Ministerial Council.

As regards your more specific questions I can provide the following answers:

1. INDUSTRIAL POLICY

The ESA Council has set up a Working Group which is supposed to come up by the end of this year with proposals that could then be endorsed by a Council at Ministerial level. The Working Group has had its first meeting on 5th February 1996.

2. INDUSTRIAL RETURN

Your question concerning abandonment of the principle of industrial return must be considered as purely theoretical as it would entail a modification of the ESA Convention; a very time consuming effort which might result in serious damages to the European space programmes. Therefore we do not want to speculate on such ideas, but to wait for the conclusions of the Council Working Group dealing with this matter.

I invite you to consult Annex V of the ESA Convention where you will notice that the term of "juste retour" is not mentioned. Only the problem of the lower limit calling for measures is included. Here the Convention mentions the limit of 0.8 and the ideal value of 1. Ministerial Councils have later on taken decisions, setting the low limit at 0.96 up to the end of 1996.

3. SCIENTIFIC PAYLOADS

A science mission generally requires the provision of:

- spacecraft
- payload: facility instrument (if applicable)
- payload: experiments (if applicable)
- launcher
- mission operations
- scientific operations and data analysis
- archives

In general it is the task of ESA to provide, **either directly or through an international collaboration:** spacecraft, facility instrument (if applicable), launcher, mission operations. National Agencies provide the experiments. Science Operations and Archives have been variously implemented and funded, according to the characteristics of each mission and the availability of funds.

A strict tradition is that National Agencies provide the so-called PI Instruments, the principal reason being that if ESA were to pay also for the instruments, constraints similar to those of the industrial return might develop. In other words, a Member State might demand ESA to select a payload on the basis of a "juste scientific return", instead of the true scientific excellence. This is not acceptable because scientific excellence is the primary objective of the Science Programme.

4. UK Participation in ESA programmes

The UK participation in the Scientific Programme, which is part of the Mandatory Programme financed at GNP scale of all Member States, stands at 14.1 per cent. The UK's overall contribution to all ESA programmes stands at 7.1 per cent which reflects the fact that the UK does not participate in certain Optional Programmes (Ariane 5, Space Station) or at low levels (see also attached graphs and tables).

Letter to the Clerk of the Committee from Dr Robert Bingham, Rutherford Appleton Laboratory (4.3.96)

Thank you for your letter asking about the possibility of producing low cost particle accelerators. As you already known the laser beat wave scheme for particle acceleration has been able to produce extremely high electric fields in plasmas and intial experiments have shown that particle acceleration can take place. However, at present it would be unwise to abandon conventional accelerating techniques in favour of plasma based accelerators.

Historically there have been numerous alternatives schemes proposed for accelerating particle which initially showed promise but were eventually abandoned due to unforseen technical or scientific difficulties in trying to produce energetic beams of interest of the high energy physics community. At the present time there is no alternative accelerator scheme for producing energetic particles for high energy experiments.

There are a number of outstanding scientific issues that have to be addressed before the beat wave scheme can be considered seriously. As you rightly comment the present experiments produce high fields only over a few millimetres at best 1cm. This has to be increased substantially to be in the 10's of centimetres or metre range. In order for this to be useful for particle physics this would require staging ie multiple accelerating stages requiring multiple lasers, this is necessary since phase slippage between the energetic particles and electric field occurs. Phase slippage occurs because the energetic particles eventually outrun the accelerating field of the plasma wave. Experiments are being conducted at present in various laboratories to see if the interaction length over which the laser beam remain focussed can be many centimeters of plasma. This is a crucial experiment, if proved impossible then the scheme fails at this first hurdle. The laser beam not only has to remains focussed over this length, but the plasma electric field that it produces must remain coherent and not be subjected to instabilities that could destroy the coherency of the accelerating field. If these problems can be solved then we are still faced with a numbers problem. Can sufficient numbers of electron in the energy range required be accelerated to be of use? This is known as Luminosity. To obtain high Luminosity requires high repetition rates, and very high power the laser systems would have to operate at about 50 times per second. This is not possible with the lasers used in the experiments at present. Other problems that still need addressing are, 1) small particle bunch lengths are required, 2) extraction and injection of the bunched beams in synchronous with the laser 3) beam quality. Experiments are being planned to address these problems.

The energy requirements will be very similar to present accelerators unless lasers become extremely efficient at present the CO_2 laser which is being used by the UCLA group is about 5 per cent efficient. We have also to consider the energy transfer efficiency from the laser to the accelerated particles.

It we can overcome the present severe scientific and technical problems, then laser plasma based schemes have a lot going for them in terms of size. At present there is no guarantee that the stringent accelerator requirements for particle physics research will be met. Since it is very early days and many principles still have to be demonstrated, a costing is not possible, but it will not be cheap. However, a small single stage laser beat wave accelerator of energies in the GeV range would be useful in other areas of research, such as a driver for new radiation sources or for applications in medical physics.

Before any scientific decision is made on building a linear collider based on the laser beat wave principle about 10 years of research and development would be required. This would not be expensive and should yield many spin-offs.

Your letter has prompted me to produce a small technical note on some of these problems, which I will forward to you as soon as possible.

Thank you for your interest.

Memorandum submitted by Professor C H Llewellyn Smith, Director-General, CERN (3.96)

INTRODUCTION

This evidence is divided into two parts—(i) general remarks on particle physics, CERN and the UK's role at CERN, and (ii) responses to the explicit points on which the Committee seeks information from CERN.

GENERAL REMARKS

1. The aim of particle physics is to understand and explain the fundamental building blocks of matter, the forces between them, and their significance for the history and evolution of the Universe.

The field of particle physics in the United Kingdom and Europe has been reviewed by several external panels of scientists, engineers and industrialists since 1985, including the Kendrew Group set up by ABRC and SERC (1985), the Abragam Committee set up by the CERN Council (1987) and the Ledwith Working Group set up by the SERC (1992)[1]. These panels were unanimous in their positive assessments of the basic science, and in their endorsements of CERN's role and future plans.

In the words of the Kendrew Group: "no one can see this field of science as other than enormously exciting, exhilarating and rewarding", and "We have been impressed by the exciting stage of development that has been reached in particle physics, by the standard of the research undertaken by UK physicists, and by the excellence of the available facilities both at CERN and at DESY. We believe that the subject is worth pursuing in the long term ... CERN is at present the leading particle physics laboratory in the world and is an inspiring example of what can be achieved by European collaboration."

In the words of the Abragam Committee: "CERN (is) one of the most remarkable European cultural achievements since the War. ... CERN's success has been an inspiration not only to the participating scientists who took part in it, but also to leaders of industry by showing them the importance of European co-operation, particularly in the field of new technologies such as informatics, new materials, instrumentation, automation and many other areas."

In the words of the Ledwith Working Group: "The general principles, features and conslusions of the Kendrew Report remain topical and relevant ... we are persuaded that construction of the LHC at CERN is the natural way forward for particle physics in Europe."

2. The primary reason for supporting basic research in particle physics must be cultural: since the time of the Ancient Greeks, if not earlier, humans have striven to understand the building blocks of matter and the structure of the Universe, and it is in the essence of mankind to push back this frontier of knowledge. Nevertheless, advances in frundamental knowledge, and techiques developed in its pursuit, have generally led later to technological and economic advances. In the words of the Kendrew Group: "it is hard to identify any of the new technologies of our time of which the root cannot be traced back to fundamental discoveries in atomic and nuclear physics." Techniques developed for modern particle physics have certainly found many other applications, as the following sample shows.

Particle accelerators were developed to do basic research, but some 10,000 are now in use around the world for research in other fields, eg, synchrotron light sources, in all areas of physical, material and surface science, as well as in biology and in industry, eg, for chip fabrication where Oxford Instruments has taken the lead, or in medical therapy. The modern particle detector techniques invented by Charpak at CERN are now also being applied for medical imaging. Finally, the Select Committee is surely aware of the global impact made by the World-Wide Web, which was invented by a Briton working at CERN, stimulated by the need to improve communication between widely dispersed groups collaborating at CERN.

Moreover, particle physics certainly plays a role in stimulating young minds and attracting them to join the scientific enterprise. In the words of the Ledwith Working Group: "It is evident that particle physics, together with astronomy, continues to provide a powerful stimulus to recruitment of high quality entrants to departments of physics and to the kindling of interest in science generally in young people." The vast majority of these young people eventually work in other scientific fields or in industry. However, many of them would not have found their way there, if their interest had not first been kindled by reading of quarks and black holes.

3. This basic field of science also arouses considerable interest among the general public. This is reflected, for example, in sales of popular books on the subject and audiences for television programmes such as the broadcasts of lectures at the Royal Institution (e.g. "The Search for Infinity", a book about particle physics and related aspects of cosmology, published at the end of 1994, has already sold about 30,000 hardback copies in English, and has been translated into four languages, with editions in a further four languages in preparation; Professor F Close's lectures on particle physics were sold out and had the Royal Institution's

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[1] Membership of the Kendrew Group: Sir John Kendrew FRS, Lord Ash FRS, Professor Sir Douglas Hague, Professor Sir Jack Lewis FRS, Sir John Mason FRS, Professor K A Pounds FRS, Lord Tombs.

Membership of the Abragam Committee: Professor A Abragam FRS, Dr M Boyer, Dr C D De Benedetti, Professor B E F Fender, Professor W Paul, Mr H Sandvold, Mr J Vodoz.

Membership of the Ledwith Working Group: Professors A Ledwith FRS, P G Burke FRS, K A Pounds FRS.
With the exception of one member of the Abragam Committee, none of the members of these groups is a particle physicist or had ever been directly associated with CERN. The majority of the members of the Abragam Committee work in industry or finance.

largest TV audience of 1.8 million). A striking recent example was the intense interest expressed by the media and the general public in the discovery of antihydrogen atoms at CERN.

CERN and research in particle physics generally enjoy considerable support from influential media. In the words of an editorial in The Times, entitled "The Centrality of CERN", which appeared when the Kendrew Report was published: "Withdrawal from CERN would be withdrawal from an unusually successful form of European joint-action and of scientific collaboration. It would mark the end of Britain's long and leading contribution to the scientific study of the nature of matter. It would do more harm to the esteem and animal spirits of the scientific community in this country than any good the redistributed funds might do."Another editorial in The Times, written in 1994, supported approval of the LHC, as did The Financial Times, which stated in an editorial entitled "Smashing Bargain': "... almost everyone is interested in the origins and future of our Universe. So the world should not hesitate to spend a couple of billion dollars on a machine that helps us to understand it."

4. The overall quality of CERN's diverse programme is demonstrated by the fact that it attracts half the world's experimental particle physicists to carry out their research here. This programme is complementary to that elsewhere, the other major players being: Germany, which operates the world's only electron-proton collider (HERA) at the DESY Laboratory in Hamburg; Italy, which operates the world's leading underground laboratory for the study of astro-particle physics at Gran Sasso and is constructing a specialised accelerator called DAFNE; the USA with four major laboratories (BNL, Cornell, Fermilab and SLAC); and Japan, where a so-called "B Factory" is under construction at KEK. There is also tremendous expertise in Russia, but the Russian home programme has ground to a halt because of lack of funding. China operates a low-energy, high-intensity, electron-positron collider in Beijing.

5. The key role in European particle physics played by the United Kingdom and its physicists has been underlined by the review panels mentioned above. In the words of the Kendrew Group: "UK particle physicists are clearly playing a full part in research of world class standard and there are good prospects of this continuing into the foreseeable future." In the words of the Ledwith Working Group: "The Working Group is unanimous in its view that particle physics in the UK is of the highest international standing."

The United Kingdom also plays a leading role in the construction of the LHC machine, which is led by a British Staff Member at CERN, and in the research and development programmes for the LHC detectors. Technically, one of the most challenging aspects of the CMS detector is the part designed to detect and measure precisely photons and electrons, in which British groups have taken a leading role.

British physicists are also prominent in setting the physics goals of CMS, and in its management: the Chairman of the Collaboration Board and the Deputy Spokesman are UK physicists. In the ATLAS collaboration, Britain provides not only the physicists responsible for the challenging system that tracks particles close to the interaction point, for the parts of the detector closest to the directions of the colliding beams, and for the so-called "level 1 trigger", but also the Chairman of the Collaboration Board. The Chairman of the Advisory Committee of CERN Users is currently British. UK industry will collaborate with university groups in designing and building parts of the detectors, and will also of course play a major role in the construction of the LHC itself.

6. Modern research in the physical sciences is expensive, and particle physics is no exception. As pointed out by the then science Minister, Robert Hughes, MP, in a speech opening the 1994 World Particle Physics conference, the average research funding of a particle physicist in the UK is about twice the average for all sciences. This is why, while praising the field, Kendrew and Ledwith looked for cost reductions. There is, unfortunately, a large irreducible cost associated with maintaining an active pressure at the front-line of particle physics. It is therefore clearly incumbent on particle physicist to strive for maximum cost effectiveness and avoid unnecessary duplication.

The cost of CERN has been effectively contained, and, as shown in Figure 1, is actually less in real terms than it was in the early 1970s. In the intervening period (i) the size and sophistication of CERN's facilities has increased enormously, (ii) the number of CERN's users has increased five-fold, (iii) the number of Member States that share the budget has increased from twelve to nineteen, while (iv) the Net National Incomes of CERN's Member States has increased substantially in real terms (the weighted average has grown 75 per cent since 1970 and 55 per cent since 1975), and the funding of most other fields of science has in general increased at least correspondingly[2].

7. The LHC is unique in the world, offering the highest proton collision energies and rates to probe the smallest scales within elementary particles, as well as heavy ion collisions to probe the highest temperatures, and—in a possible later phase—electron-proton collisions. The uniqueness of the research opportunities offered by the LHC is recognised by the world community of particle physicists, and offers a first chance to craft a truly global project.

Non-Member State particle physicists are seeking to collaborate with member State physicists in the LHC experimental programme in unprecedented numbers, as are nuclear physicists from Member States—not, unfortunately, including the UK—and elsewhere who wish to study heavy ion collisions. As described in the reply to *Question 3* below, these physicists contribute to the construction and operation of the detectors and bring considerable benefits for CERN, and those countries with a major involvement are expected to contribute to the construction of the accelerator.

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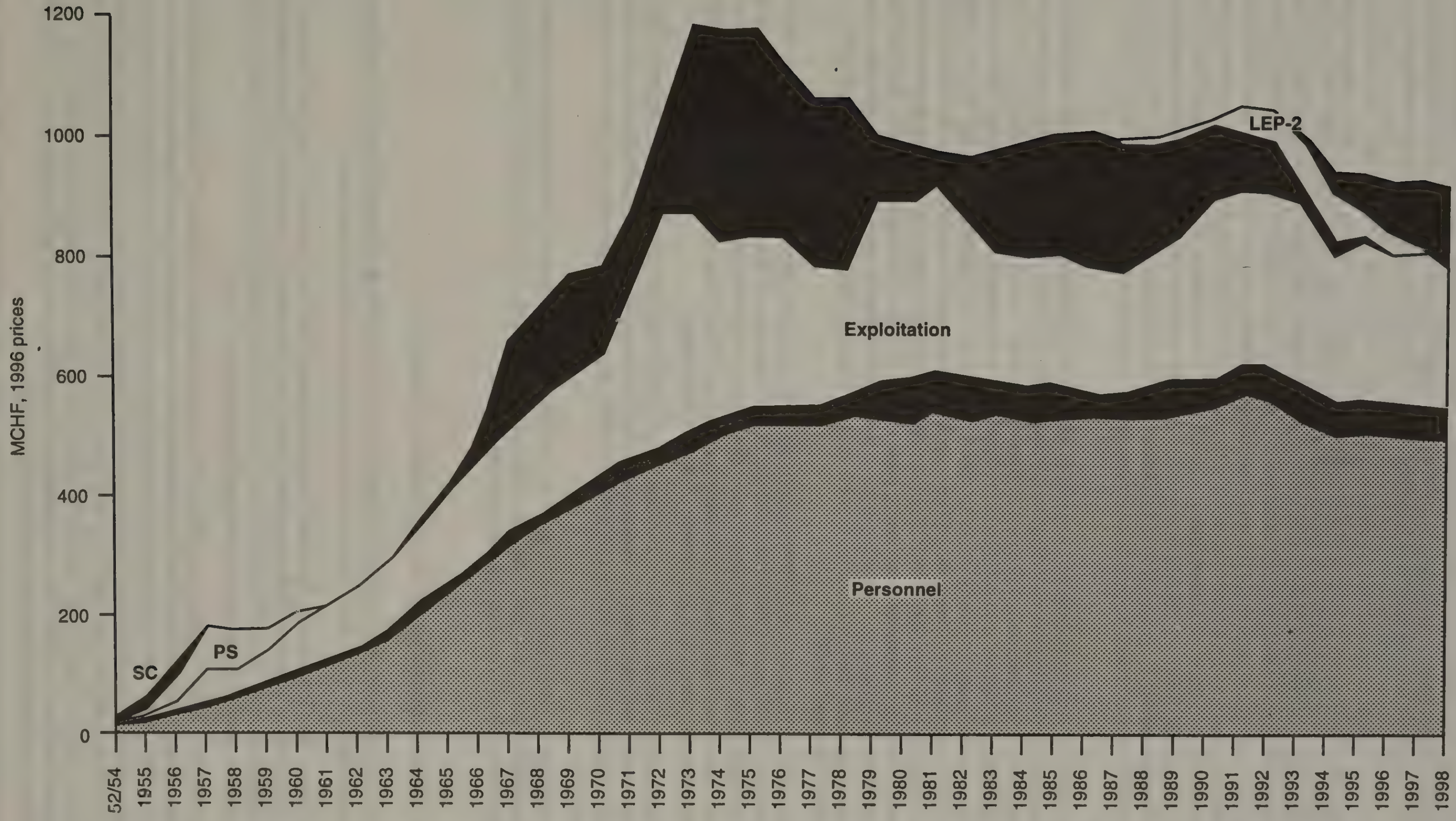
[2] Funding of conventional nuclear physics in the UK is an exception, having been strongly reduced in comparison with particle physics which has been considered to have higher priority.

Figure 1



CERN Expenditure in 1996 prices

The evolution of the CERN budget, corrected for inflation (using the CERN index, as calculated for materials and granted for salaries). The modest rise during the 1980s was accounted for by new Members joining, especially Spain which (re)joined in 1983 and now contributes almost 10% of the budget. The assumptions underlying the future projection are described in the text.

CERN's tradition of incorporating existing infrastructure in new projects and re-using existing facilities, which has made possible the construction of ever larger and more sophisticated scientific instruments without increases in the budget, will be continued with the LHC. The LHC will be perhaps the most cost-effective accelerator ever build in the sense that some two-thirds, by cost, of the project already exists (tunnel, four pre-accelerators, etc). The necesary expertise also exists at CERN, and could only be re-trained and assembled at huge expense. CERN has an enviable record of completing its projects on time and within budget. The cost estimates for the LHC and its detectors have been reviewed and accepted by several international panels.

8. CERN's original proposal was to build the LHC on the basis of a budget held constant in real terms, which required painful priority setting and the closure of excellent facilities, eg LEAR—where antihydrogen was recently discovered—which will be closed at the end of this year. The LHC Project was finally unanimously approved by the CERN Member States on the basis of a three-year budget freeze, to be followed by 1 per cent indexation assuming that inflation is 2 per cent, ie a budget that is decreasing in real terms. In accepting the challenge of launching the most technically exacting project CERN has ever undertaken under these conditions, and having already included in the original proposal the elimination and reduction of other programes up to the limit of acceptability, the CERN Management has committed itself to improving efficiency and productivity, eg CERN plans to reduce staff numbers from some 2,850 today (already down from 2,967 when the HLC was approved in December 1994) to around 2,150 when the LHC is completed. Experience over the last year supports our confidence that this will be possible, but it will be extremely difficult.

In the context of cost containment, the level of salaries at CERN deserves comment, especially in view of remarks suggesting that they are not being controlled properly. In fact, salary levels fell 6 per cent in real terms in the years 1991–95 and actually fell again as part of the recent salary settlement, which was below inflation and included other measures that will further reduce costs in the future. In considering CERN salaries, as the CERN Council did very carefully in 1995 when sixteen of the nineteen Member States supported the settlement, it is necessary to (i) note that 65 per cent of recruitment is from industry, and that CERN must be able to recruit from Member States with the best employment conditions if it is to be a genuinely international organisation, (ii) take account of purchasing power parities (which differ greatly from the exchange rate for £/Swiss franc comparisons), and (iii) bear in mind that CERN salaries have been pushed below those of other international organisations in Geneva, as well as international scientific research organisations elsewhere, such as ESO, ESA and EMBL.

9. Despite the freeze of the CERN budget, the UK has experienced a large increase in the cost of the subscription to CERN since 1994 because of the fall of the value of the pound relative to the Swiss franc. A number of other CERN Member States have experienced a similar problem, but it has been exacerbated somewhat in the case of the UK by the relatively rapid growth of the economy, as a result of which the UK's contribution has increased as a percentage of the CERN budget.

This has clearly created a problem, but one that experience shows may be only transitory. This point can be seen in Figure 2, which shows the evolution of the UK's contribution, in real terms, over the last 20 years. This figure suggests that rises in the UK's subscription, expressed in pounds, are generally compensated by decreases later.

It is important to note that some 95 per cent of CERN's expenditure is in currencies that remained in the ERM, or in Swiss francs, so CERN has certainly not experienced a windfall gain in the purchasing power of its budget as a result of recent changes of exchange rates.

REPLIES TO SPECIFIC QUESTIONS RAISED BY THE SELECT COMMITTEE

1. *The Committee would appreciate information about the CERN budget, in particular, for how many years are countries committed to the CERN budget, and how can they end their commitment?*

According to the Convention, Member States can leave CERN at the end of any year after giving notice at least 12 months in advance (disengagement might not, however, be completely instantaneous in view of certain obligations, e.g. to the Pension Fund). However, the unanimous approval of the LHC project was generally felt to imply a long-term commitment to remain in CERN.[3]

The level of the CERN budget is voted year by year according to the Convention, although normally four-year rolling budgets are adopted, with indexation then voted year by year. However, when the LHC was approved in 1994, the CERN Council unanimously adopted a Resolution which included statements that (i) the budget contributed by Member States would be frozen for three years, and (ii) planning should proceed on the basis that it will be indexed 1 per cent per year from the end of 1997 onwards assuming an average inflation rate of 2 per cent. The Council Resolution also stated that any contributions from non-Member States would be used to speed up and improve the project, not to allow reductions of Member States' contributions, and negotiations have proceeded on this basis.

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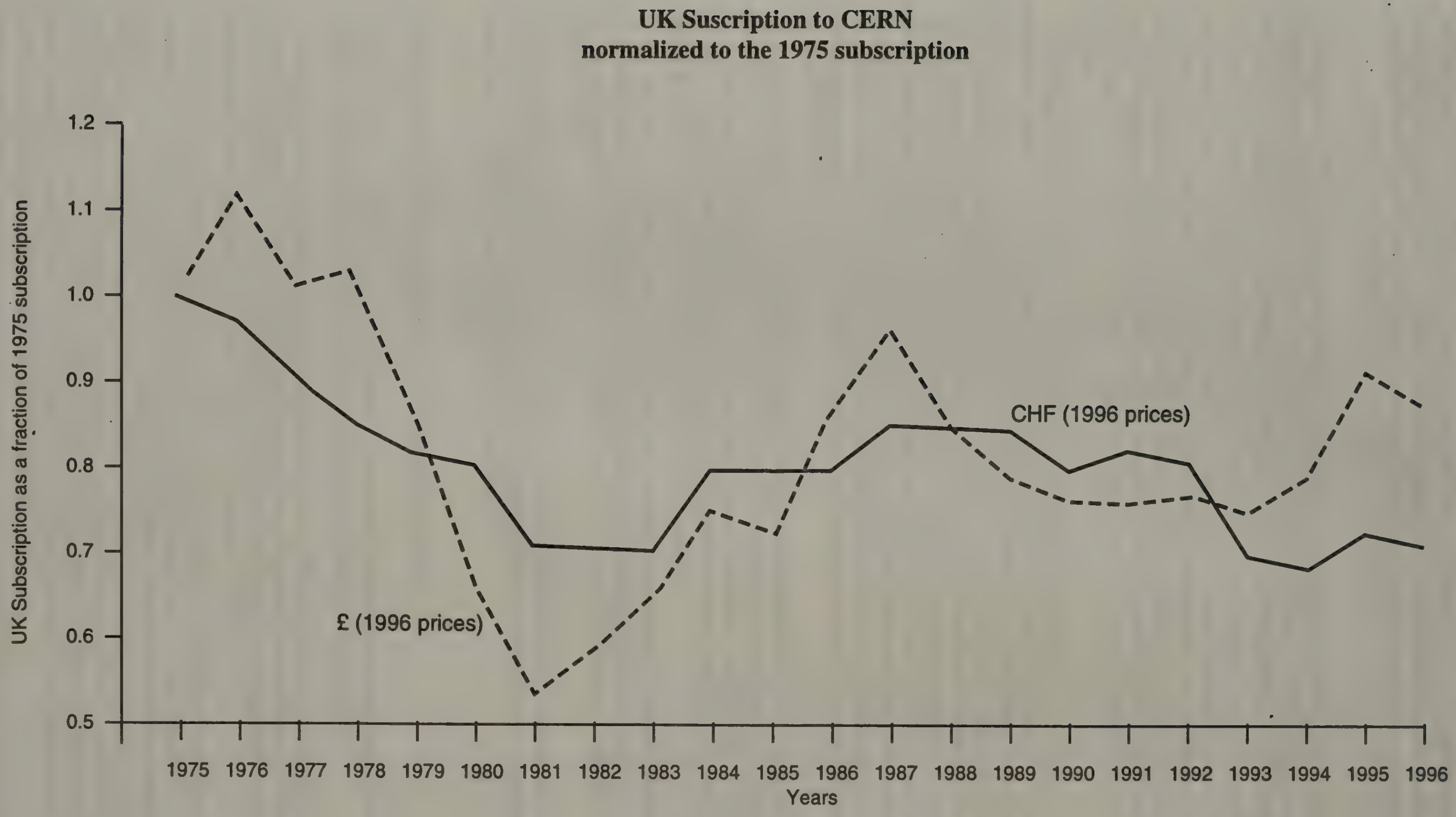
[3] In the corresponding case of the LEP project, the UK said explicitly that it would remain in CERN throughout the construction period unless the project turned out to be much more costly than had been planned and could not be completed in a reasonable timescale, or the SERC's budget fell in real terms over a period of time.

2. *Is it possible to make a distinction between capital and running costs expenditure of projects such as LEP or the LHC, and is it helpful to make such a distinction?*

The CERN budget presented to its Council each year is broken down into capital and running costs of different projects and activities: a partial breakdown of material costs can be seen in Figure 1. However, the fact that common infrastructure and administration support both the running of ongoing programmes (such as LEP) and new capital projects (such as the LHC), and that many individuals work on both, complicates the picture, and the common costs are generally not attributed to different activities in the budget.

Council is presented with a global budget for any major capital project such as the LHC, and with closing accounts, as was done in 1990 for the first phase of LEP. There is, however, some flexibility to transfer funding in a given year between different programmes, which is very useful in optimising the overall programme and managing cash flow.

Figure 2



Evolution of the UK's subscription to CERN *i)* in Swiss francs (CHF) corrected for inflation as in Figure 1, and *ii)* in £s corrected for inflation using the UK's GDP deflator (for iconvenience, this was calculated using the average exchange rate of each year except for 1996 where the exchange of January has been used: in practice we understand that the UK buys forward). The trough in 1981, when the old method of contribution which was more sensitive to exchange rates was in use, occurred because of the exceptional strength of the pound when the UK became a net oil exporter.

3. *Which non-Member States now participate in CERN and on what terms do they do so; what negotiations are currently taking place?*

Today some 30 per cent of CERN's 6,000 scientific users come from over 30 non-Member States, and this looks set to rise to around 45 per cent at the LHC.

This reflects the fact that all experiments in particle physics are performed by international collaborations, and non-Member State physicists invariably work together with Member State physicists. The presence of the non-Member State physicists, and their contributions to the construction and operation of the detectors, therefore allows CERN to mount a broader and richer programme than would otherwise be possible, to the great benefit of Member State physicists. Our colleagues from other regions also make considerable intellectual contributions; in particular, the designs of the LHC detectors have been greatly improved by the ideas brought by ex-SSC physicists.

The largest contingent comes from the US and the second largest from Russia. In the case of the US, the previous transatlantic balance has broken down, although substantial numbers of European (including British) particle physicists are involved in experiments at US particle physics laboratories which have facilities complementary to those at CERN (establishing figures is difficult as it is not easy to define the boundaries of particle physics). The US Department of Energy notes that there are substantial imbalances in the other direction in other fields, and vigorously defends the principle of free access, pointing to the US record of opening its doors in all fields (eg access to NASA scientific missions, and to results of research on the human genome) and to the past situation in particle physics. The Russian users include a significant number of engineers and applied physicists whose presence at CERN replaces staff effort, and should be counted as a contribution to the laboratory.

Since 1980, the global particle physics community has followed guidelines proposed by the International Committee for Future Accelerators (ICFA), which are based on open access without charging for operation of the accelerators or provision of the basic infrastructure, with all participants in experiments expected to contribute pro rata to the construction and operation of the experimental detectors. The rationale underlying these guidelines is the undoubted benefits of outside involvement.

As stated above, the Resolution adopted unanimously by the CERN Member States when the LHC was approved includes the statement that non-Member States' contributions to the project (ie to the construction of the collider; contributions to the detectors are taken for granted) should be sought "to speed up and improve the project, not to allow reductions in the Member States' contributions". This is fundamental for our negotiations as it is clear that external authorities, such as the US Congress and the Japanese Government, wish to see value added for any contributions.

Negotiations are currently completed or in progress with six countries. In alphabetical order:

— *Canada* has offered an in-kind contribution[4] worth $C35 million over five years: CERN has asked for cash as well and for a commitment for a further five years.

— *India* has offered an in-kind contribution worth $12.5 million and an agreement concerning this contribution will be signed shortly.

— *Israel* has agreed to contribute 2 million Swiss francs/year, which is 20 per cent of the contribution it would pay as a Member.

— *Japan* has already contributed 5 billion Yen (approximately £31 million) and the Minister of Education, Science & Culture told the Press that Japan is thinking of contributing three or four times as much again during the LHC construction period. While this statement may have been optimistic, a recent visit to Japan has confirmed that there will almost certain be substantial further contributions.

— *Russia* is likely to be ready soon to sign an Agreement to make an in-kind contribution worth 66 million Swiss francs (some £36 million).

— *The USA* has invited CERN to start formal negotiations concerning a contribution. The negotiations are complicated by the current budgetary difficulties inthe US and the difficult relations between the US Administration and the Congress in general, and the Department of Energy (DOE), which is the lead US organisation in the negotiations, in particular. The DOE is taking to CERN in terms of substantial sums which, however, fall short of the Member States' expectations.

4. *How effective are the efforts to spread the commissioning of equipment more evenly between Member States?*

Presumably this question refers to the spread of industrial contacts. CERN has introduced the notion of a "return coefficient" for each country defined as the ration of (i) the value of the contracts obtained to (ii) the value that would be obtained if contracts were distributed exactly proportionally to contributions. In 1993 Council agreed that, as a goal, it would be desirable for all Member States to have return coefficients of at least 0·8. As a result of determined efforts by CERN, the return coefficients of France and Switzerland (the countries perceived as benefiting most from CERN contracts) have fallen from 1.69 and 5.02 respectively

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[4] Here and below the contributions quoted are to the machine; in all cases there will be appropriate contributions to the detectors.

(averaged over 1991 to 1993) to 1.13 and 2.85 for commitments made in 1995. This is an important change, and in addition all Member States are now getting some significant orders from CERN, which was not the case in the past.

The UK's return coefficient was 0.63 averaged over 1991 to 1993, 0.76 for commitments in 1994, and 0.46 for 1995. The recent drop is being analysed. It is thought to be a fluctuation due partly to a reorganisation of the UK structure responsible for strengthening and maintaining industrial links with CERN, and to the simultaneous reduction in funding for this activity, into which other Member States put more effort. The response to the first call for tenders for the LHC suggests that the UK is well placed to capture future orders.

5. *What benefits does participation in an experiment bring, given that results are shared between Members and, indeed, published?*

It is generally recognised that only direct participants in research in any given field can be at its cutting edge. Those who do not participate directly are doomed to a second-rate future, as new knowledge reaches them in a delayed and diluted form, so that their understanding of the fundamental science and their ability to contribute to its advancement are diminished. There is an analogy with watching the Olympics on television sitting in an armchair, as opposed to participating in an Olympic event. This argument applies equally to the development and application of new technology, either required for new cutting-edge projects or appearing as spin-offs. UK industry will have only secondary and indirect access to these if UK physicists are not directly involved in the basic research work.

If they were to be denied participation in the essential experiments, UK scientists would become demoralised and lose their ability to teach and inspire new generations of students. The experience of other countries demonstrates that when part of the science base is destroyed (eg, in Germany over fifty years ago) it required generations to grow back. Moreover, basic scientific knowledge cannot simply be bought: despite extraordinary efforts to boost its efforts, Japan is not yet able to compete equally with Europe in particle physics.

The UK has an enviable record in this field. Some fraction of the respect that the UK commands in the world, as well as its self-respect, are linked to its perceived role as a leader in this and other aspects of scientific culture.

6. *Is the level at which the UK can participate in CERN's programmes of concern*

- — *in terms of its effect on CERN's own scientific programmes?*
- — *in terms of the health of particle physics in the United Kingdom?*

As has been mentioned above, UK physicists have until now been able to play a major role in CERN's research programme, and some UK citizens have been essential in the operation of CERN. The importance of the British role has been maintained by a policy of withdrawing from low-priority programmes and concentrating efforts in a limited number of areas, with effective collaboration between different research groups. Clearly, the impact of the UK effort could have been greater if more funding had been available: the UK's financial participation in experiments at CERN is proportionally lower than that of the other major Member States. Conversely, any substantial reduction would greatly harm CERN's programme in the crucial aspects where UK effort is focused.

The health of particle physics in the United Kingdom is currently good, but it is percarious. Further financial malnutrition would jeopardise the ability of the UK's particle physics community to maintain its current responsibilities for key parts of experiments, which are frequently among the most interesting scientifically and the most challenging technically. This ability is essential for the present and future health of particle physics in the United Kingdom.

Final Remark

The CERN Management looks forward to welcoming the Select Committee to CERN. We will be very pleased to answer further questions then or before the visit, and invite advanced notice of any requests for more detailed information.

Memorandum submitted by British National Space Centre (25.3.96)

Overview of UK space policy and programmes

The Government's policy on civil space activities is co-ordinated by and implemented through the British National Space Centre (BNSC) which reports to the Minister for Science and Technology, Mr Ian Taylor MBE MP, and the President of the Board of Trade, The Rt. Hon. Ian Lang MP. BNSC is partnership of eight public sector organisations, namely the Department of Trade and Industry, including the Office of Science and Technology, the Particle Physics and Astronomy Research Council, the Ministry of Defence, the Natural

Environment Research Council, the Meteorological Office, the Department of the Environment and the Foreign and Commonwealth Office. BNSC is located, for organisational purposes, in the Department of Trade and Industry from which most of its staff are drawn. Personnel from the Particle Physics and Astronomy Research Council (PPARC) staff the Space Science Division at BNSC.

2. The main aims of the Government's policy on civil activities are as follows:

- — to support uniquely valuable space science
- — to improve the competitiveness of the UK space industry in world markets
- — to encourage the development of operational systems for the future
- — to encourage commercial returns, especially to users of space data and facilities
- — to help us to understand our changing planet
- — to make known the potential and achievements of UK space activity
- — to make optimum use of private finance.

3. Expenditure by Government on civil space amounts to just under £200 million a year. Two-thirds of this is devoted to investment in programmes of the European Space Agency (ESA), to which HMG is the fourth largest contributor (out of the fourteen member states). The remainder goes on UK national programmes, most of which are aimed at general exploiting the UK's investment in ESA but also include bilateral programmes with other countries.

4. The breakdown of the expenditure for 1995–96 is given in the following table:

ESTIMATED UK GOVERNMENT CIVIL SPACE EXPENDITURE IN FINANCIAL YEAR 1995–96

	ESA Contributions *£m*	*National Expenditure* *£m*
Earth Observation	48.58	45.80
Science/Microgravity	39.32	13.21
Telecommunications	11.66	4.00
Technology	0.26	0.31
Other National	—	0.26
ESA General Budget etc	16.85	—
Transportation	7.43	0.11
TOTAL	124.1	63.69

5. The BNSC publication "UK Space Activities 1994–95", which is attached, highlights the key developments last year. The main policy issues facing the UK are discussed in the document "UK Space Policy — a discussion document", which Mr Ian Taylor issued for consultation at the end of 1995 following a Symposium which the Minister chaired for the UK space sector at Surrey University last autumn. This document is also attached. A further policy document, taking account of the consultation, will be issued by Mr Taylor for discussion at a Symposium to be held at the University of London on 25 June.

RELATIONSHIP BETWEEN THE SCIENCE PROGRAMME AND OTHER PROGRAMMES

6. PPARC is the partner in BNSC which is responsible for Government funding of space science. This makes up one-third of the total UK contribution to ESA and one-fifth of the total expenditure on UK national programmes, as shown by the table in paragraph 4 above. PPARC's funding is allocated by the President of the Board of Trade as Cabinet Minister for the Office of Science and Technology, now part of DTI, and this is divided by PPARC between space science, ground-based astronomy and particle physics.

7. The ESA space science programme is one of ESA's so called "mandatory" activities. Consequently the science programme subscription made by each member state is in strict proportion to the member state's Net National Income. This is different from most other ESA programmes, such as Earth Observation and Telecommunications, which are optional, allowing a member to decide whether or not to participate and if so at what financial level. When the budget for science was considered at the ESA Ministerial Council at Toulouse in October 1995, Mr Taylor succeeded in gaining agreement from the Ministers of the other ESA member states to freeze the budget for the next five years, except to the extent that inflation exceeds 3 per cent. The Ministers endorsed measures to improve the efficiency and cost-effectiveness of ESA, which should benefit all its programmes, mandatory and optional.

8. The direct financial contributions of the four largest ESA member states to the ESA space science programme last year are given below. Further in-kind support of the ESA space science programme is provided by all the ESA member states (eg operational support and archiving).

DIRECT CONTRIBUTIONS TO ESA's SPACE SCIENCE PROGRAMME IN 1995
(in millions of ecu)

Germany	79.75
France	56.56
UK	48.22
Italy	56.42
Other ESA countries	100.67
TOTAL	341.62

Note the value of the ecu used by ESA in 1995 was 1 ecu = £0.77597.

9. 1995 and 1996 are particularly prolific years for the ESA science programme, with three science mission launches. The Infrared Space Observatory (ISO) was launched successfully in November 1995 from ESA's launch site at Kourou, French Guyana; the Solar Orbiting and Heliospheric Observatory (SOHO) was successfully launched from Cape Canaveral in December 1995; and Cluster, a group of four satellites to complement SOHO, is due for launch on the first Ariane 5 flight from Kourou in May 1996.

10. As far as launchers are concerned, the Government has succeeded in bringing about, along with other ESA member states, a reduction to commercial levels in the Ariane launch prices charged to ESA. ESA's Science Programme, like the other ESA programmes can normally be expected to give preference to Ariane (as laid down in the ESA Convention). Among the factors which may give rise to launchers other than Ariane being used are joint missions with other Agencies, eg NASA, where the launch is part of an overall deal, or operational considerations.

11. As well as their subscription and in-kind support for the ESA science programme ESA member states additionally contribute, through their own national programmes, instruments for the ESA science satellite payloads and data analysis of the information flowing back from the satellites. Most countries also have space science programmes which are separate from ESA. While the UK subscription to the ESA science programme is expected to remain roughly constant over the next three years, the national space science programme is declining.

12. The most recent comparison of the national spend of the major ESA member states on space science, calculated on a common base, is for 1990-92. This is set out in the following table, with the figures given as percentage of the individual member state's ESA Science Programme subscription.

NATIONAL SPACE SCIENCE PROGRAMMES (1990-92)

	Germany	*France*	*Italy*	*UK*	*Average for other ten ESA member states*	*Average for all ESA member states*
Instrument support for ESA Science Programme, expressed as a percentage of country's subscription to ESA Science Programme	34	29	21	31	21	27
National and bilateral space science expenditure outside ESA, expressed as a percentage of country's subscription to ESA Science Programme	65	34	43	23	33	40

Source of data: European Space Agency

13. The figures in the table above indicate that in the early 1990s the UK used about the same proportion of its NNI as other ESA member states for the provision of instruments for ESA science programme payloads, but a considerably lower proportion on its space science expenditure outside the ESA programme.

Memorandum submitted by younger members of the particle physics research community in the United Kingdom (29.4.96)

This letter is presented by younger members of the particle physics research community in the United Kingdom to the Select Committee on Science and Technology. We wish to express our views upon the particle physics programme in the UK, and upon the most recent proposals presented to us by the Chief Executive of PPARC. Signatories include PhD students, post-doctoral researchers, and staff recently appointed to permanent positions in Universities and the Central Laboratory for Research Councils.

1. The first objective of this letter is to clearly affirm to the Committee the enthusiasm we have for this field of research. The quest for a fundamental understanding of our world has always been one of the driving forces of the evolution of society, and we wholeheartedly believe that particle physics is a natural and important part of this. The quality and depth of the UK contribution to this vibrant field was clearly highlighted at the recent annual conference of the High Energy Particle Physics Group of the Institute of Physics, which attracted a record attendance. The meeting affirmed the inspiration and excitement which first drew us to this subject. This enthusiasm is widely evident at the school level: the latest PPARC survey shows that particle and sub-atomic physics draws many students to the Sciences.

We are committed to the future of the subject, principally through participation in the LHC programme which the UK, with the other CERN member states, approved in December 1994. The UK is also prominent in a number of smaller experiments, and in theoretical programmes, all of which are well focussed on the objectives set out consistently over the last five years in the "Particle Physics 2000" document, and subsequent updates. The programme addresses the key issues in particle physics well into the next century. We inherit this major responsibility willingly, and wish very much to be able to maintain the respected position which the United Kingdom holds in these international projects.

We therefore hope that we leave the Committee in no doubt as to the sincere belief we have in the importance of this work, and the dedication we have to its future success.

2. The second objective of this letter is to make the Committee aware that we have very serious worries about the actions being taken by PPARC, actions which we believe to be damaging to the future of the particle physics programme.

We were dismayed by the plan put to us by the Chief Executive of PPARC at a meeting on the 10 April. We give only the briefest summary here, and refer the Committee to the appendix for a fuller description of our understanding of these matters. The plan seeks to take over the entire responsibility for the CERN subscription, an international treaty obligation which fluctuates as a result of changes in GDP and exchange rate, within a budget which is fixed in pounds sterling. The plan also makes the assumption that the Government will be willing to try to re-negotiate the treaty on which it has already agreed. We believe this to be an ill founded assumption since there is no special case which the UK can make, and we would in any case be seeking a reduction when the UK economy is improving. Failure to negotiate a reduction in the CERN subscription, which is highly likely, will result in severe cuts, possibly in excess of 20 per cent in the funding for the exploitation of current commitments.

The damaging effect of these proposals cannot be overstated. They do not provide for a long term programme which allows us to exploit fully the facilities in which we invest, and are a recipe for long-term decline. The far reaching cuts which would result will bite deeply into our ability to participate effectively in existing and future experimental and theoretical projects. The extensive job losses which would follow will have a drastic effect upon the morale of young researchers on short term contracts. This would be a blow against the community's very future, against those who will implement it.

In summary, we hope that the Committee will take note of our commitment to the future of particle physics. We hope that the Committee will be able to recommend steps which will allow PPARC to support the particle physics programme more effectively.

APPENDIX

DETAILS OF THE PPARC PROPOSALS

Our understanding of the proposals put to us by the Chief Executive of PPARC is:

- The implementation of a long term "business plan" which incorporates the CERN subscription in a way which potentially cripples the programme. The plan proposes to take over responsibility for the fluctuations due to the rise in GDP and exchange rate changes, within a total budget which is fixed in pounds sterling. The CERN subscription is determined under international treaty, and such fluctuations are clearly not under the control of PPARC. At present such fluctuations are not the responsibility of PPARC, but are compensated for by the OST through a mechanism established specifically to protect research councils from fluctuating costs of international treaty obligations.
- The plan is based upon the assumption that the UK will be released from its obligations under the international treaty, to which the Government has already agreed. It proposes that the UK government will agree to try to re-negotiate the funding formula to obtain a reduction in the subscription. This seems ill founded, as the UK has no special case to put as would be required under

the CERN constitution. In particular, this proposal is made at a time when the UK contribution to CERN has increased partly because the UK economy is improving relative to other member states, thus we are unlikely to be able to base our case on a weakening UK economy.

- The plan also assumes that if any reduction were obtained, then PPARC would be able to retain this. This may not be the case as at present the mechanism by which fluctuations in the CERN subscription are met by the OST is such that any increase or reduction is necessarily provided for or retained by the OST.
- If it does not prove possible to negotiate a reduction in the CERN subscription, as seems likely, then a severe reduction of around 20 per cent in the "domestic budget" will be implemented. The domestic budget covers all costs other than the CERN subscription. This will have a drastic effect on the particle physics programme.
- The Chief Executive stated clearly during questioning that the plan did not stem from any review of the merits of the scientific programme or a careful assessment of the likely effect that the implementation of the plan would have.

Memorandum submitted by Professor C. H. Llewellyn Smith (5.96)

UTILITY FROM PARTICLE PHYSICS

1. Introduction

The primary goal of particle physics is to enlarge mankind's knowledge of the cosmos. However:

(1) It is possible that, as in the case of fundamental research in the past, new laws of nature with enormous utilitarian and economic consequences will be discovered (electromagnetism, quantum mechanics, . . .)

(2) New devices, techniques and technologies developed by or for particle physics often turn out to have other unexpected applications of great value (cancer therapy, medical imaging, radiation processing, . . .)

(3) The specifications of equipment ordered from industry for research in particle physics are often at or beyond the limits of current know-how. In meeting this challenge, manufacturers often improve their core competences, and improve quality and productivity, as well as developing new products and technologies.

It is arguable that the economic value of (2) and (3), minus the opportunity cost, should be set against the cost of particle physics (it is also arguable that the value of the World Wide Web, invented at CERN, exceeds the total investment in the Laboratory since its foundation). This note summarises some of these effects, starting with (3) which—although not the most important—is easiest to quantify, and working backwards to (1).

Quantification is very difficult, not least because a large part of the benefits of the numerous medical spin-offs of particle physics is humanitarian rather than economic. Other non-quantifiable benefits of particle physics, which are not treated here, are its role in attracting the young to science[1]) and the value of the training in an international environment given to graduate students.

2. The Added Value of Contracts Related to Particle Physics

Two studies[2])[3]) have attempted to measure a quantity which the authors call the

"Economic utility" = increased turnover + cost savings

resulting from contracts awarded by CERN (sales to CERN are not included in the increased turnover). This was done by interviewing a very large sample of firms that had high-technology contracts with CERN in the period 1973-82 (in electronics, optics, computers, electrical equipment, vacuum, cryogenics, superconductivity, steel and welding, and precision mechanics). The estimates were made by the industrial managers, and not by CERN, and in cases of doubt the lowest figure was taken.

The conclusion is that high-technology contracts placed by CERN have an economic utility (normalised to the value of the initial contracts) of 3.0, ie, every £ paid to an industrial firm generates £3 of utility. The total utility of CERN contracts has a value that is over 60 per cent of the total CERN budget. It is notable that only 24 per cent of the CERN-related increased sales was in the high energy and nuclear physics market, the rest involving unrelated fields such as solar energy, electrical industry, railways, computers and telecommunications.

It is interesting to note that a similar study commissioned by the European Space Agency (ESA) has given the same multiplier factor of 3, however nearly 80 per cent of the ESA-related increased sales remain inside the space sector and the remaining is mostly in aeronautics and defence.

3. Spin-offs

For ease of presentation, the sample of examples given below, is divided somewhat arbitarily into applications of accelerators, applications of particle detectors, spin-offs related to informatics, and technological spin-offs.

3.1 *Applications of Accelerators*

The first accelerators were built to study the nucleus and they were then developed for particle physics. These accelerators turned out to have many totally unexpected applications and it is estimated that today there are well over 10,000[1] with a value well in excess of $10 billion[2] of which only a handful (about 100) are used for nuclear and particle physics. Many applications of accelerators have been listed and discussed in a personal note submitted to the Select Committee by Dr Peter Williams from which some of the following is taken.

In the semiconductor industry, ion implantation is one of the key stages in "doping" semiconductors during the processing of silicon or gallium arsenide to produce integrated circuits. Very many generic types of such semiconductor devices require ion implantation processing which uses a charged particle accelerator, usually a heavy ion "linac".

Industry size: semiconductors	—	greater than $100 billion pa.
equipment	—	greater than $1 billion.

X-ray lithography is a new processing technique currently being pioneered by IMB, Oxford Instruments, NTT, Sumitomo and numerous other Japanese companies. A compact electron synchrotron is used to provide the X-ray source which then prints sub-micron features on semiconductor wafers. X-ray lithography will almost certainly be required for at least part of the processing of above one Gigabit memory chips by the year 2000, opening up a potentially large new market ($100 million per annum for equipment alone). Oxford Instruments developed the Helios Company Synchrotron with the help of the Daresbury Laboratory and the SERC (Daresbury, it should be recalled, was initially established as a high energy physics research facility).

Other industrial uses include:

- Food processing by sterilisation to preserve freshness in fruit. At present it is a small market in total size but may grow if concerns regarding the long-term safety of the procedures can be allayed.
- Non-Destructive Testing: a variety of accelerators is used in systems for radiography of welds on nuclear power stations or large steel structures and in the aerospace industry. Oxford Instruments and Rolls Royce are pioneering the application of cyclotrons to the neutron radiography of air frames and aero-engines. At present *all* turbine blades on *all* aero-engines must be neutron radiographed at a reactor location. With a compact cyclotron, a "mobile" source of neutrons is provided which can be transported to a manufacturing or airframe testing environment. The USAF are currently engaged in trials and the Korean Government is showing signs of interest in civil aerospace applications.
- Radiation processing (eg, to modify materials such as polymers, radiation vulcanisation of rubber, purification of industrial gases) and sterilisation (to turn industrial and domestic sewage sludges into fertilisers or additives to fodder; for medical sterilisation—radiation can be used to sterilise products after they have been packed).

In *medicine*, electron beam accelerators ("linacs") are widely used in cancer therapy, usually by producing a secondary γ-ray or X-ray beam which impinges on the tumour. A different form of accelerator—the cyclotron—is in use in experimental trials in the UK, USA, Japan, France, Belgium and Germany for both proton and neutron tumour irradiation. Proton and ion synchrotrons are being developed for use in cancer therapy at CERN and elsewhere. The importance of these applications is obvious, as it is estimated that one person in eight in the western world is treated by an accelerator during their lives. The industry size for linac-based radiotherapy facilities is well in excess of $1 billion per annum. Many radiopharmaceuticals used in therapy and in diagnostic imaging are prepared by using a cyclotron to bombard a target to yield radioisotopes via nuclear transmutation. Imaging techniques such as "SPECT" and "PET" are rapidly entering fields such as cardiology and neurology as new diagnostic tools.

Industry size: $1–10 billion per annum.

Accelerators, based on those developed for particle physics, have become important tools for *basic and applied research in other fields.* Synchrotron light sources, such as the Daresbury facility and the ESRF in

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[1] A figure of "some 10,000" was quoted for the year 1994 by W Scharf from the Warsaw Technical University, author of two reference books on the Applications of Particle Accelerators, one in technology and research, the other in biology and medicine—but several hundreds of units are added every year for cancer therapy alone.

[2] This figure does not include the large research machines like those at CERN, DESY (Germany), FERMILAB (US), SLAC (US) or KEK (Japan).

Grenoble, are used by condensed-matter physicists, biologists, etc, as are spallation neutron sources, such as the world-leading ISIS facility at DRAL.

Two other potentially very important uses of accelerators should be mentioned. The first is *power generation* either in fusion driven by a heavy ion accelerator, or in fusion in an internally confined plasma heated by an accelerator, or in an accelerator driven fission. Renewed interest in the latter idea was stimulated by the successful development during the 1980s of components of particle detectors called energy compensated calorimeters. It has recently been vigorously pursued by C Rubbia at CERN, who has invented what he calls an "energy amplifier". If successful, which will depend on further advances beyond the current frontier of accelerator technology, it will constitute an intrinsically safe fission reactor which, in contrast to conventional reactors, only produces relatively short-lived radioactive waste, and does not produce material that could be used in weapons.

The second is the use of accelerators to *incinerate radioactive waste* and the world's stockpiles of plutonium. Here again C Rubbia is pursuing a promising novel approach at CERN, which has a real chance of providing a practical solution to one of the world's major problems.

3.2 *Applications of Particle Detectors*

Detectors developed for particle physics have found numerous other applications. Examples derived directly from work at CERN include—

- Uses of multiwire proportional chambers, developed by G Charpak at CERN (for which he was awarded the Nobel Prize in 1992):
    - in commercial lorry and container inspection systems (at Le Havre and the Eurotunnel terminal)
    - research use: in medical imaging (positron emission tomography; body scanners); in studies of animal metabolism; in astrophysics to study cosmic showers.
- Uses of crystal detectors, based on Bismuth–Germanium–Oxide (BGO) developed for LEP experiments at CERN (prior to this development, sodium-iodide—a "noisier" material with a slower response—was generally used):
    - in medical imaging (positron emission tomography; body scanners): the number of BGO-based detectors in use in medicine must be in the hundreds
    - in security (eg, plastic explosives detection at airports)
    - in non-destructive testing in industrial research laboratories (eg, quality of welding of seams in long pipelines)
    - in research in biology, condensed matter physics, astrophysics, and optics.

  Research is now underway at CERN on new crystals in preparation for LHC experiments, which require further enhancements of detection speeds, and is likely to have as big an impact as the introduction of BGO in the 1980s.
- Semiconductor detectors and associated electronics: advances in semiconductor technology permit the construction, for particle physics experiments, of arrays consisting of thousands of sensor elements per cm^2, each on the same silicon chip with the associated electronics required to process the signal, digitise it and pass it on to computers for fast information extraction. The application of these detectors include
    - monitoring of cosmic rays during space flights
    - mammography for cancer screening
    - DNA sequencing
    - peptide synthesis analysis
    - metabolism analysis.

  Many of these applications are still at the development stage and have not yet reached the commercial market. A further limitation for medical diagnostics is the need to expose the patient to a certain amont of radiation. This may however be radically changed by recent progress in data acquisition electronics resulting from R&D for the LHC detectors. The increased speed and sensitivity will allow to reduce by at least an order of magnitude the radiation dose necessary to perform a diagnostic while improved image processing techniques are expected to facilitate considerably early breast cancer detection.

3.3 *Spin-off related to Informatics*

The most widely used device developed at CERN is undoubtedly the World Wide Web. It was initially designed to help communication within the particle physics community. Physics research groups now consist of several hundreds of members scattered in numerous research institutes and universities. They needed to have access to common databases, exchange and edit common documents such as scientific articles, reports, engineering designs and so on. They all had access to the Internet but needed an appropriate software tool which was developed for them by CERN. As is well known, its convenience made it spread rapidly to the whole academic world and from there to universal use.

Other informatics development resulting from or stimulated by particle physics include:

- Massive parallel processing (this has been stimulated particularly by theoretical particle physicists)
- Use of simulation programmes (Monte Carlo) for cancer therapy planning
- Use of accelerator fault diagnosis software for remote powerline monitoring (CERN participated in an ESPRIT project on this topic)
- Use of particle track recognition algorithms for on-line quality control
- Distributed process control with the associated data acquisition modules (CAMAC) and digital network for data transmission.

3.4 *Technological Spin-offs*

The following is a sample of technologies that have been developed for, or largely stimulated by, particle physics, together with some examples of devices whose origin can be traced directly to CERN:

Superconductivity:[3] For more than 50 years following the discovery of this phenomenon in 1911 by Kammerlingh Onnes, there were few scientific or industrial applications of this breakthrough. The discovery of the A15 alloys such as Nb_3Sn changed that and facilitated an "enabling technology". The first applications, however, were by high energy physicists in making magnets and other devices for accelerators. As ever, high energy physics produced the *drive* in the development of the technology.

Even more importantly, this pushed a requirement for usable engineering materials. Superconducting cables and wires suffer from a curious handicap of "AC" losses, but pioneering work at the Rutherford Appleton Laboratory by the high energy physicists produced multifilamentary wires and cables which are today the bedrock of a diverse range of applications, many of which have a British presence.

(i) Magnetic Resonance Imaging or MRI: without cheap, reliable multifilamentary conductors developed initially for high energy physics applications, there would simply not have been an MRI Scanner. Today, with superconductivity "tamed", there are over 8,000 world-wide (Oxford Instruments manufactures one per day).

Industry size: $2 billion p.a.

(ii) NMR Spectroscopy: MRI grew out of NMR, a fundamental chemical research technique, which also uses high field superconducting magnets where the UK is again a world leader.

Industry size: $250 million p.a.

(iii) The upgrade of LEP to achieve a collision energy of 200 GeV with an acceptable power consumption has led to the development of superconducting RF cavities to provide the energy necessary to compensate the strong synchrotron radiation losses. The application of these devices is for the moment limited to scientific research facilities but it is likely that, because of their efficiency and compactness, they will be used instead of classical accelerators.

(iv) Finally, the world's largest project in superconductivity will be the Large Hadron Collider (LHC) at CERN. This will again undoubtedly *drive* the technology hard (and is already doing so) with numerous spin-off benefits and opportunities. High-temperature super-conducting current leads made of the new materials discovered at IBM in 1986 will be used extensively. The Collision Magnets and the associated detectors will push the technology even harder.

Cryogenics is closely associated with superconductivity as all present industrial superconductors must operate at low temperatures to reach the superconducting stage. Present industrial facilities operate at 4 K (or—269°C, the temperature of liquid helium). In view of the large cooling requirements of its facilities, CERN has pushed industry to produce more efficient and reliable refrigerators. For the LHC, even lower temperatures (1.9 K) are needed with as a result further improvements. Below 2.1 K helium becomes superfluid, dramatically changing its properties (eg, its thermal conductivity is 10,000 times that of Copper), making it a unique engineering material in search of new applications! Cryogenics, although at higher temperatures, has extensive applications in the gas industry. One can certainly not claim a direct effect of particle physics to this already mature field. However, it is likely that the efficiency and reliability improvements induced by particle physics will yield sizeable benefits.

Vacuum: Keeping particle beams circulating for hours and even days in a ring requires the production of high vacuum to avoid losses by collisions with the residual gas. CERN has pioneered many vacuum techniques in the 1970s for the construction of its Intersecting Storage Rings (ISR), the first large proton collider.

Vacuum is today essential for numerous manufacturing processes in the food, the pharmaceutical and in particular the semiconductor industries for integrated circuits, the basic components, among others, of computers and mobile telephones. The market size of these products expressed in dollars is in the nine-digit range (well over $100 billion).

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[3] Most of this section is directly taken from the note of Dr Peter Williams.

Electrical Engineering: Progress in RF and microwaves has been mainly drive-by the requirements for radio and TV broadcasting and radar, however the needs of particle physicists for powerful accelerating systems has stimulated the development of more efficient klystrons, the special type of vacuum tubes which generate the high-frequency driving accelerating structures. The resulting power savings will probably be passed on to devices intended for other applications. The same holds for thyratron switches which power the fast magnets used to inject or extract particle beams from circular accelerators and colliders.

Another application has been the development at CERN during the 1970s, in collaboration with industry, of non-flammable electrical power and signal cables for use in accelerator tunnels and underground experimental areas. Contrary to expectations their use did not become more widespread, but recent disasters (fires at the Düsseldorf Airport and Crédit Lyonnais) might make their use mandatory.

Extensive development also occurred for power converters which drive the thousands of magnets to be found in a laboratory like CERN. The improvements for better efficiency (lower losses) and higher accuracy have found their way into commercial systems, for instance the powering of the already mentioned MRI devices. In particular, CERN-designed power supplies are now used in Oxford Instruments' MRI Scanners.

Geodesy and geology: High-energy particle accelerators and colliders must satisfy very stringent geometrical conditions. Bending high energy protons is at the limit of technology and tunelling errors in excess of a few centimetres would make the machine totally inoperable, while for high energy electrons the synchrotron radiation losses would be unacceptable. The CERN survey group has therefore developed a range of highly accurate surveying instruments and techniques in particular for underground tunnelling. Some of these were used for the Eurotunnel. The use of microwave techniques for CERN accelerators has been successfully tested by Swiss and French geologists to detect underground water-filled caverns (geological radar). The use of this scheme is envisaged for the future Swiss alpine tunnels which have costs estimated in the £10 billion Swiss franc range.

Ship and oil rigs building: Synchrotron magnets are measured very accurately to a precision better than 0.1 millimetre before being installed. It is essential that they are transported without vibrations or mechanical deformation between the measurement laboratory and the underground tunnel. Special vehicles were developed for this purpose in the 1970s for the ISR at CERN. As reported in ref. 2, the use of similar transport techniques in ship yards allows large elements to be prefabricated in workshops, which is considerably more efficient than the traditional method.

4. Direct Applications of Discoveries in Particle Physics?

New fundamental discoveries frequently have enormous utilitarian and economic consequences.[4] It is easy to imagine particle physics making "useful" discoveries. For example, a heavy electron-like particle with a relatively long lifetime could catalysis fusion (such particles have been found, but unfortunately the best candidate for catalysis of fusion—a particle called muon—does not live quite long enough); if, as believed by many theorists, magnetic monopoles of a certain type exist, a single monopole could produce hugh amounts of power by catalysing the decay of protons. These are long-shots, and it would be rash to claim that fundamental discoveries in particle physics are likely to have direct applications. It is certain, however, that mankind will not be able to exploit facts and laws of nature that remain unknown!

References

(1) PPARC 1995 Survey of New Physics Undergraduates.

(2) H Schmied, CERN Yellow Report CERN/75–6; also in IEEE Trans. Eng. Mgt. EM–24 (1977) 125.

(3) M Bianchi-Streit et al, CERN Yellow Report CERN/84–14, summarised in Czech J Phys B38 (1986) 23.

(4) For a review see O Barbalat, Physics World (May 1991) 31.

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[4] A famous statement by the eminent physicist, and one-time Research Director of Philips, H G B Casimir puts the case[5]): "Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in and had not contributed to wave mechanics or the theory of eletrons in solids. It so happened that the inventors of transistors were versed in and contributed to the quantum theory of solids. One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics. One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps—only it didn't happen that way, and there were the Curies and Rutherford and Ferni and a few others. One might ask whether an electronics industry could exist without the previous discovery of electrons by people like Thomson and H A Lorentz. Again it didn't happen that way. One might ask even whether induction coils in motor cars might have been made by enterprise which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that. Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasised the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of twentieth-century innovation which is not indebted in this way to ask scientific thought". For further discussion see reference 6.

H G B Casimir, contribution to Symposium on Technology and World Trade (1966).

(6) J A Kay and C H Llewellyn Smith, Fiscal Studies, Vol 6, No 3 (1985) 14.

Letter to the Clerk of the Committee from the Office of Science and Technology (4 June 1996)

Thank you for your letters of 10 and 16 May.

You asked, in your letter of 10 May, about the original motivation for supporting the areas of research covered by PPARC. The Government has supported research in these areas for many years. Records here do not go back far enough to allow me to determine the original motivation for Government support. However there is no doubt as to the Government's current motivation for supporting such research, which is clearly stated in the mission given to PPARC by the White Paper "Realising our Potential". The main objective is to improve understanding of the concepts and principles underlying physical phenomena and their consequences.

You asked whether Government support (not just UK Government) for particle physics research arose from a belief that the results of the research would have important applications in the areas of defence and energy. Article II of the Convention establishing CERN (which entered into force in 1954) states that CERN would have no concern with work for military requirements. The content of the research programme is determined by the particle physics community itself, not by those with an eye on potential applications. PPARC's mission, to which I have already referred, requires them to take into account the potential for contributing to UK industrial competitiveness and quality of life but does not single out specific applications. This is because, unlike the other Research Councils, PPARC is almost exclusively responsible for supporting basic research. It is in the nature of such work that any practical applications are likely to be diverse and pervasive.

You might be interested to know that a "History of CERN", in three volumes by A Hermann, J Kruge, U Mersits and D Pestre was published by North Holland Publishers, Amsterdam. The first volume (published in 1987) deals with the setting up of CERN in 1954, and contains case studies of the development and policy decisions in Britain, France, Germany and Italy. Unfortunately, I do not have a copy and I am told that it is out of print in the UK, but still in print in the USA.

Let me now answer each of the questions in your letter of 16 May in turn:

(1) The DGRC topslices the science budget to ensure money is available to offset the effects of exchange rate fluctuations on international subscriptions. How is the basic level of subscription, to be borne by PPARC before such compensation for fluctuations each year, determined?

The mechanism was introduced by the DGRC to give effect to the committment made by the Government in paragraph 6.17 of the White Paper. It applies to the UK subscription to CERN, which is wholly paid by PPARC, and the PPARC share of the UK subscription to ESA. In both cases the base level, currently the level of subscription for the calendar year 1994, is paid by PPARC from its allocation. The fluctuations beyond PPARC's control, as defined in my answer to your next question, are funded from the Science Budget as a whole.

(2) It is our understanding that the topslicing of the budget to cover fluctuations in the exchange rate does not include increases in subscriptions due to the growth of GDP. Is this correct?

No. The compensation given to PPARC from the Science Budget for variations in the CERN and ESA subscriptions covers variations due to changes in exchange rates and Net National Income (NNI). (NNI, rather than GDP, is used in calculating Member State contributions.)

(3) It is our assumption that likely increases in international subscriptions, whether from exchange rate fluctuations or GDP variations, is discussed in the course of the PES round. Is this correct?

It is not Government policy to disclose the details of negotiations between departments and HM Treasury in the Public Expenditure Survey, but such pressures will clearly feature.

I hope you find these answers helpful and look forward to seeing your committee's report. Please do not hesitate to contact me if you have any further questions.

Extract from a letter to the Committee Assistant from PPARC (5 June 1996)

"DOMESTIC" EXPENDITURE ON INTERNATIONAL ACTIVITIES

Your letter mentioned the point that our category "domestic" expenditure does in fact include certain international subscriptions and commitments—a point picked up also by your consultant, Ian Harrison. I should explain that the ESA and CERN subscriptions are always identified separately as "International Subscriptions" both because they are the subject of inter-governmental treaty over which we have no direct control, and because they are reported to Government separately and cannot be vired with other subheads.

In practice the majority of our work can be carried out only in international collaboration. Thus, all except one of our ground based telescopes are supported to varying degrees by international collaboration—from our 25 per cent share in the new GEMINI twin 8-m telescope with the US Canada and others, to the 50 per cent share in the AAT which you mention, and the La Palma telescopes and James Clark Maxwell (millimetre wave) telescope in which we have the majority stake. In space, UK instrumentation for ESA missions is always carried out in collaboration with other countries' scientists even though it is accounted for under the "domestic" heading. And much work in particle physics, though accounted as "domestic" in practice involves more or less formal collaboration with other countries, for example our scientists' use of the German particle physics facilities at DESY (Hamburg). It would be impossible without disproportionate effect to produce detailing costings over time for all these elements, but the following indicate the orders of magnitude for the current (1996–97) year which are broadly typical:

International commitments reported under "domestic"		*£M*
by treaty—	Anglo Australian Telescope	1.53
	European Incoherent Scatter project (EISCAT)	0.57
interagency agreements—	Ground Based telescopes	11.5
contributions to international projects—(eg through MOUs) (estimate)	eg contributions to space instrumentation projects (£10M), particle physics experiments (£10M) and various ground based projects (£5M)	25.0
		38.6

Because of the difficulty in disaggregating the third category, the figure of £25M (and hence the overall total) is accurate only to the nearest £5M.

These figures re-inforce the point made in our first memorandum to the Committee about the essentially international nature of modern particle physics and astronomy. We would be happy for you to circulate this information to the Committee.

Letter to the Clerk of the Committee from Professor Ken Pounds (7.6.96)

PPARC 1996 Business Plan

In my letter of 15 May I said I would write again about our Business Plan when Council had met to discuss it on 21-22 May. Since then you have written on 17 May, mainly about the international subscriptions issue.

2. We have sent, by separate mail, 15 copies of the Business Plan as submitted to OST. You have had a copy of our News from Council which summarises the outcome of Council's discussions. (I enclose a further copy for ease of reference). I believe this provides the most effective summary response to the questions in your letter of 2 May. I would re-inforce in particular:

- the Council's continued commitment to its high priority activities in education and training, industry links and PUS programmes;
- its wish to maintain a programme in ground and space based astronomy and planetary science that exploits its investment in facilities and in the scientific opportunities provided by membership of ESA;
- its strong commitment to the LHC as the centrepiece of the UK and European (and shortly world) particle physics programmes, and the importance of a domestic programme on a scale to exploit the CERN membership;
- its intention to seek to reduce its exposure to the CERN subscription through negotiation with Government and other member states;
- the need for PPARC to get a special capital injection of order £60 million in total over 7-8 years in order fully to benefit from the investment (of around £500 million) which the UK will be making in the construction of the LHC;
- (until some better method can be agreed; see paras 6-11) the importance of retaining the current OST mechanism for spreading across the whole Science Budget the cost of exchange rate and NNI fluctuations in the CERN (and ESA) subscription.

3. The News from Council (paragraph 4) summarises the planning proposals agreed by Council to implement these principles.

The need for an exceptional capital injection for participation in LHC science

4. In his 1993 "Boundary" report to the Chancellor of the Duchy of Lancaster on the Research Councils, the former Chairman of the ABRC, Sir David (now Lord) Phillips, said of PPARC:

> "I note that the programme of PPARC relies very heavily on international collaborations, with more than half its financial resources being devoted to the payment of subscriptions which secure access to facilities, but which do not provide for their exploitation. In addition, much of the domestic programme comprises long-term commitments (for example, to space missions), with lumpy expenditure profiles that may cause handling difficulties within a budget that is significantly

> smaller than that of SERC. The new Director General may wish to consider with the PPARC's Chief Executive possible measures to help alleviate such planning difficulties."

5. At the same time, the need for additional funds to enable the UK community to participate effectively in the LHC science programme has been flagged up with increasing urgency in every Business Plan or Forward Look since 1992, and was implicitly recognised in 1994 when the PPARC came into being. Work done for the Particle Physics Committee's Resource Planning review and in developing the 1996 Business Plan, now allow a reliable estimate of the minimum additional resources required.

6. The issue is intrinsically one of obtaining scientific return and value for money from past and future investment. The UK has invested heavily in its particle physics community and in CERN in preparation for the LHC. The comparatively low price of the LHC comes from the effective use of existing facilities at CERN. The UK will, therefore, have contributed some £500 million directly to the project: full and cost-effective exploitation of such a large investment of public funds is essential.

7. Council is, therefore, seeking an exceptional injection of new funding over the 7-8 year period to 2005. With the additional funding requested the UK will consolidate its leading position in several key areas, securing adequate scientific and technical return on its considerable investment, and will be able to meet some 75-80 per cent of its pro-rata collaborative responsibilities. The resources required are given below (£ million):

1997–98	*1998–99*	*1999–00*	*[2000–01*	*2001–02*	*2002–03*	*2003–04*	*2004–05]*
2.0	4.50	10.0	[13.00	12.00	9.00	8.00	7.00]

where the figures for 1997–98 to 1999–00 are cash planned and the figures from 2000–01 are at constant 1999 prices.

9. Once the LHC is operational it is expected that the CERN baseline budget, freed of the burden of LHC construction, will reduce by up to 20 per cent in real terms. At the same time the cost of maintaining an adequate UK programme to exploit LHC science opportunities will fall to 1994–95 levels. Thus the total requirements for particle physics from 2005–06 onwards could be up to 20 per cent less in real terms than at present.

10. The Select Committee may consider that a phased funding mechanism will also be required by other Research Councils who have to cope with major capital items, such as oceanographic research vessels or major central facilities, eg, neutron or synchrotron radiation sources.

The handling of international subscriptions outside the Science Budget

11. In our main Memorandum (paras 4.8 to 4.10) we recalled the Government's explicit rejection of the case for handling international subscriptions outside the Science Budget but, noting the wider advantages to the UK of international scientific collaboration, invited the Select Committee to consider alternatives to the present way of funding international subscriptions. In our oral evidence Peter Williams confirmed that it was PPARC's view that the balance of UK interests was strongly in favour of the CERN and ESA subscriptions being handled from outside the Science vote.

12. The Government's case in the 1993 S and T White Paper is that ". . .such subscriptions (should) be seen as part of our scientific endeavour rather than our foreign policy". However, this does not take account of the fact that the level of such subscriptions can be affected (in a major way) by factors which have nothing to do with science, and are totally outside the control or even influence of the scientific community. It is clear that these external changes distort the scientific priorities which the scientific community and Government have developed over time.

13. The two key factors are the Net National Income (NNI) on which each nation's relative contributions to CERN and ESA are calculated; and the exchange rate which determines the actual sterling cost of the subscription at the time when it is paid.

14. We observe the particular linkage between NNI and the Scientific Budget and PPARC. As the nation's wealth increases, so does its NNI and thus so do its legal commitments to the CERN and ESA subscriptions. However, unless the Science Budget grows in line with the growth in NNI, increased international subscriptions will inevitably take up a growing proportion of that Budget—whether or not this is consistent with Government or PPARC scientific policy.

15. Our Memorandum pointed out that it is only in the UK that the linkage between subscription and related domestic budget is so close that a rise in subscription for non-science-related reasons cuts directly into the ("domestic") funds available for exploiting that subscription. The Committee has been given figures which demonstrate how far, over time, domestic funds have fallen in relation to the subscriptions. If this trend continues, as our baseline funding would suggest, the result would be increasingly poor value for money from these major programmes; effectively it would mean the UK taxpayer subsidising other nations' scientific research.

16. In summary, we agree with the Government that the basic level and content of inter-governmental research programmes, in volume terms, is one for which scientific rather than foreign policy considerations

should predominate and on which the scientific community and PPARC should be closely consulted. However, we maintain that:

- the present system introduces serious distortions from time to time, because non-scientific factors (national wealth and exchange rates) affect scientific priorities; this leads to a reduced overall return on UK investment and can cause unnecessary disagreements and loss of influence with our international partners;[1]
- an alternative system in which the subscriptions were borne outside the Science Budget, eg, by Treasury direct or by DTI centrally, or by the same budget that handles UN, OECD, NATO Science Programme subscriptions, would allow those non-science factors to be taken into account in a wider context, but should also allow the scientific community to be actively involved in planning the content and absolute level of subscriptions. As a minimum, PPARC recommends the variable margin of the subscriptions should be handled independently of the Science Vote.

OTHER COUNTRIES' MECHANISMS FOR INTERNATIONAL SUBSCRIPTIONS

17. Your letter of 17 May invited our comments on statements in the House of Lords' Report into "International Scientific Programmes" regarding mechanisms for funding major international subscriptions in other European countries. To the best of our knowledge, the general principles described in that Report remain true, although in both Germany and France the names and some responsibilities of the ministries concerned have changed.

18. In both cases the international science subscriptions form part of much larger budgets covering a range of other large subscriptions. While future budgeting pressures on the subscriptions may start to impinge on domestic budgets there is little evidence of this effect to date, and as we have shown in our Supplementary Memorandum, their levels of domestic expenditure remain several times the size (pro-rata to NNI) of ours.

19. In the case of Italy, we understand that it is the Italian Ministry of Foreigh Affairs that is responsible for Italy's subscription to CERN, (not their National Institute for Nuclear Physics (INFN) as reported in the FCO evidence to the Lords inquiry) although it is the INFN that funds domestic particle physics.

20. While we have limited information on this issue for the smaller member states, a definitive up-to-date account could presumably be obtained through our Embassies via the FCO.

DUAL SUPPORT TRANSFER

21. You reported to Geoffrey Findlay the Committee's interest in this topic. I understand you have seen the Coopers and Lybrand report and you will know, therefore, it is a complex issue in which useful data is difficult to obtain. The key points which PPARC would want to make are:

(a) that in the allocation of the DS funds, PPARC received less than it needed to fulfil its obligations under the new system, particularly in relation to technical staff transferred from HEFC to PPARC support. (We have the evidence for this should you need it);

(b) that PPARC disbursed its allocation of DS funds in full to research grant holders in universities, according to the principles agreed at the time. (We have the relevant data on this also).

22. You may be aware that discussions are under way about the possibility of effectively "reversing" some of the transfer back to the universities by means of increasing the overheads paid on the staffing element of research grants, from 40 per cent to 45 per cent. Should such an increase be agreed, PPARC has argued that it should be explicitly linked to an increase in transparency (and accountability) by the universities on the use of the funds concerned. We are concerned that such a reverse transfer would inevitably reduce the success rate of grant applications.

PPARC REPRESENTATION AT ESA MEETINGS

23. I apologise for omitting from my last letter—in error as you rightly guessed—the issue of PPARC representation at ESA meetings, and how this differs from the practice under SERC. In fact it differs little.

24. UK representation at the ESA Science Programme Committee (SPC) is normally provided by the PPARC Head of Astronomy, Dr Paul Murdin, (who is also Director, Science BNSC) and Professor Mike Cruise (University of Birmingham), a distinguished space astronomer in his own right and Chairman of the PPARC/BNSC Space Science Advisory Panel. It is open for me personally also to attend the SPC and this I do occasionally.

25. The UK has just one delegate to the ESA Council, currently Derek Davis, Director General BNSC. PPARC has the right to attend and speak at any Council meeting where scientific issues are under discussion.

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[1] PPARC's experience to date quantifies the problem. As the Committee will know, the CERN subscription rose by £16M pa from 1994–95 to 1996–97. Preliminary OECD figures for member state NNIs in 1995, combined with the current exchange rate, would REDUCE our 1997–98 subscription by some £10M.

Over the past two years this role has been undertaken primarily by the PPARC Director of Science, Dr Ian Corbett, But I have also attended on two occasions.

26. I maintain a good working relationship with the ESA Director of Science, Dr Roger Bonnet, whom I have known for many years.

Letter to the Clerk of the Committee from Profesor Roger Cashmore and Dr John Garvey (13.6 96)

DUAL SUPPORT TRANSFER TO PARTICLE PHYSICS COMMITTEE

We understand from Dr Brian Foster that the Select Committee has asked for a brief history of the Dual Support transfer as it affected Particle Physics grants. As Chairman of the Particle Physics Grants Subcommittee (PPGSC, responsible for awarding programme support to university groups working in experimental particle physics), and Chairman of the Particle Physics Committee (PPC) at the time of the DS transfer, we set out below a summary of the main points.

1. The transfer of support for research from the UFC to the SERC was intended to be neutral. Our interpretation of this on the PPC and on the PPGSC was that for each unversity research group the level of support via the SERC after the transfer would be equal to the combined level of support from the SERC and the UFC before the transfer. For university groups supported by the SERC the level of UFC support was well documented as it had to be included in each grant application, and this occurred every two years. Support from UFC sources for experimental particle physics within the universities has been high, particularly as regards staff effort, but also in terms of departmental grants for equipment, consumables and travel.

2. At the time the transfer was announced, therefore, SERC already had available full details of the level of UFC support provided to experimental particle physics groups, and hence the funds which would be required to transfer to SERC the full costs associated with that area of research. This information was verified and updated with each individual group, and is available if required.

3. This information was not, however, used to establish either the total sum to be transferred from the UFC to the Research Councils, or the amounts to be allocated to individual Councils, Boards and Committee. Instead, a formula was arrived at as a result of a Pilot Study where Research Council officials interviewed Vice-Chancellors, Finance Officers, etc, from a selected group of universities; this group was claimed to be representative but in fact included only one university (Birmingham) with a particle physics experimental group. The recommendations from the Pilot Study on the amount to be transferred, therefore, failed to take account of the traditionally high level of support to particle physics groups.

4. The allocation initially proposed for particle physics, therefore, fell far short of the established requirement, which had been communicated by the PPC and the PPGSC to the SERC in April 1992. We met several times with SERC officials to make the case for an increase, pointing out the shortcomings of the Pilot Study, and presenting the data on current UFC support to each group. We argued that the discrepancy between the requirement and the proposed allocation suggested that either the total sum being transferred from the UFC to the Research Councils was insufficient, or else it was being divided up wrongly among the different subject areas. Our arguments were not accepted, though the accuracy of the supporting evidence we presented was never questioned.

5. At this point, we started to see an apparent redefinition of the purpose of the transfer. Whereas originally we had been told that the aim was to transfer all costs associated with research in a particular area to the relevant research council, we were now informed that this was not realistic, and that some costs must be found from the 40 per cent overhead to be paid on all salaries. There was no indication that this change was accepted by the universities, and we never got to a position where we might have been able to negotiate an arrangement along these lines. It seems, too, that each university treats the 40 per cent overhead on staff salaries in a somewhat different way, though information on this point is very hard to obtain.

6. After a lot of pressure had been applied by the PPC, the Chairman of the SERC, Sir Mark Richmond, agreed to transfer £1.3 million per annum to particle physics from the DS transfer contingency reserve. This was added to the initial allocation. The first call on the total transferred resources was to provide the full 40 per cent overhead on the existing SERC-supported posts. The remainder represented about two-thirds of what was required to make the overall transfer truly neutral. This was the level of allocation finally achieved in October 1992. A further small increase was obtained in 1994, with the winding up of SERC. The Table gives the required level of support and the allocated level of support for the year 1994–95 (at current year prices).

Table

DETAILS OF REQUIRED AND ALLOCATED SUPPORT FOR THE YEAR 1994–95

	required *£ million*	*allocated* *£ million*
Overheads on existing SERC-supported staff	1.42	1.42
Staff transferred from UFC to SERC support (including overheads)	4.70	3.26
Non-staff direct costs	1.08	0.80
Total	**7.20**	**5.48**

The numbers indicated a shortfall in the level of support transferred compared to that required for neutral transfer of £1.72 million.

7. We may add that the PPGSC adhered rigorously to the conditions of the transfer, in allocating initially the additional funding to groups solely for the transfer of staff posts and other items verified as previously supported by the UFC. The fraction of required resources given to each university research group was the same. In subsequent grants rounds the peer review system has operated, and the levels of overall support for each university group has changed. Also since 1992 the lack of compensation for inflation, particularly pay awards, has exacerbated an already bad situation and reduced further the support which the PPGSC can supply.

8. At the conclusion of the DS transfer exercise in 1994, our protests to the SERC concerning the loss of support in what was still being described by them as a neutral transfer, led to a new interpretation by them of the meaning of neutral. We were told at that time that neutral meant that all the money diverted from the UFC had been allocated in university grants. We are sure that this is true. However, it seems likely that not enough resources were diverted, and that the pattern of allocation was not sufficiently accurate to maintain the same level of support over all the sciences. For particle physics the reduction was very serious as is indicated in the Table above, and has had a lasting effect.

We hope that this provides the background which the Committee requires in considering the history of the DS transfer. Please let us know if you require any further information.

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